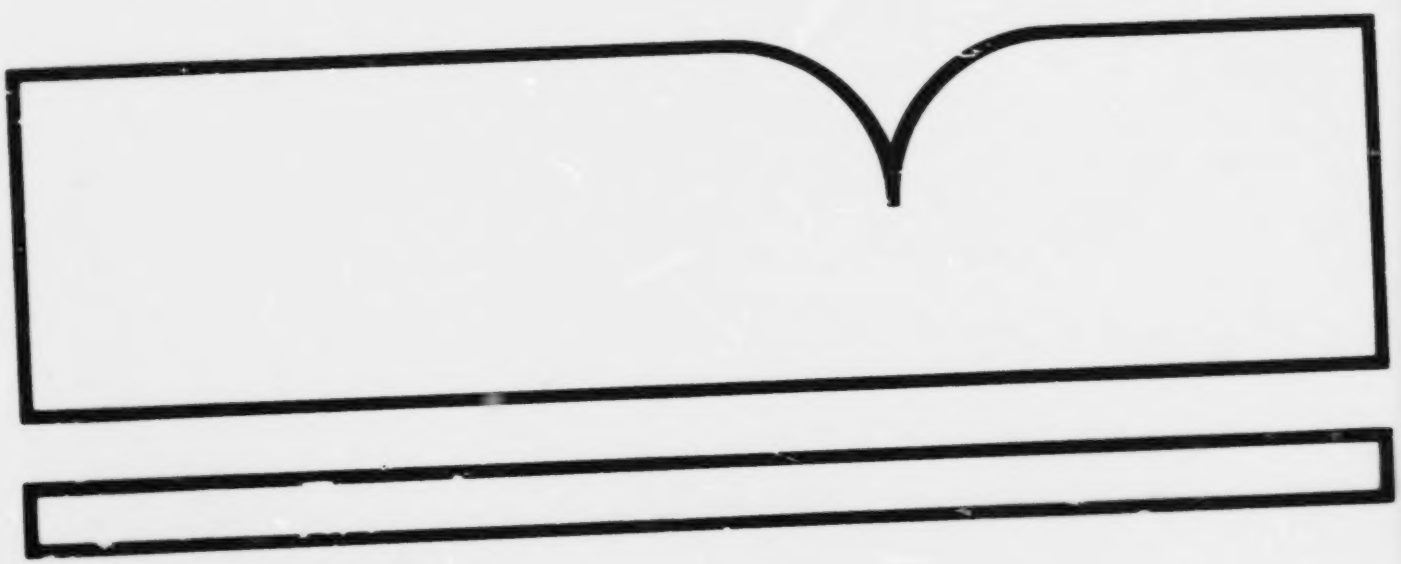
PB90-256785

User-Friendly Data Entry Routine for the ESP Model

Southern Research Inst., Birmingham, AL

Prepared for:
Environmental Protection Agency, Research Triangle Park, NC

Jul 90



U.S. Department of Commerce
National Technical Information Service
NTIS

PB90-256785

EPA/600/8-90/060
July 1990

A USER-FRIENDLY DATA ENTRY ROUTINE FOR THE ESP MODEL

by
M. G. Faulkner
Southern Research Institute
Birmingham, Alabama 35255

Cooperative Agreement No. CR 812811

EPA Project Officer
Louis S. Hovis
Air and Energy Engineering Research Laboratory
U. S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA (Please read Instructions on the reverse before completi		
1. REPORT NO. EPA/600/8-90/060	2.	3. PB90-256785
4. TITLE AND SUBTITLE A User-friendly Data Entry Routine for the ESP Model		5. REPORT DATE July 1990
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) M. G. Faulkner		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Southern Research Institute P. O. Box 55305 Birmingham, Alabama 35255-5305		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. CR812811
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air and Energy Engineering Research Laboratory Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 6/88 - 9/89
		14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Louis S. Hovis, Mail Drop 4, 919/541-3374.

16. ABSTRACT The report is a user's manual for an interactive data entry program that greatly simplifies the creation and modification of electrostatic precipitator (ESP) model data files. Routine use of the interactive program, written for IBM PC-compatible computers, will eliminate a major source of error in computing with the EPA/Southern Research Institute ESP model, which has very exacting format requirements for the input data sets. The report describes each step necessary to create data files. Data files written using this program on a PC may be transferred to a main frame without change.

17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Electrostatic Precipitators Mathematical Models Data Processing Computer Programs	Pollution Control Stationary Sources Data Entry Personal Computers	13B 13I 12A 09B
18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified 20. SECURITY CLASS (This page) Unclassified	21. NO. OF PAGES 83 22. PRICE

EPA Form 2220-1 (9-73)

ABSTRACT

All versions of the EPA/Southern Research Institute (SRI) electrostatic precipitator (ESP) performance model have very exacting format requirements for the input data sets. SRI has written a program for EPA which greatly simplifies the creation and modification of ESP model data files, thereby eliminating one of the major sources of error in the use of the model. This program, which is written for IBM PC-compatible computers, has the following features:

- The data are displayed in a set of menu-driven data forms. Each item is entered by typing the correct number in the space provided.
- Each data item is identified by description as well as by variable name.
- The program reads and writes data files in the standard EPA/SRI ESP model data format. The data files written by the program may be used by any EPA/SRI ESP model.
- When the program begins, a set of ESP data is displayed as a guide in selecting suitable data values. Any ESP data set may be used for the startup data.

This report serves as a user's manual for the data entry program. It describes each step that the user must follow in order to use the model successfully. A complete description of the ESP model input data is included as an appendix. Forms for organizing data before using the data entry program are also included.

EPA REVIEW NOTICE

This report has been reviewed by the U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policy of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

CONTENTS

Abstract ii
Figures iv
Tables v

1. Introduction 1
2. Conclusions and Recommendations 4
3. Use of the Data Entry Forms 5

Calculation Parameters 5
Physical Data 5
Particle Size Data 10
Sectional Data 10
Sneakage, Sigma G, Opacity, and Rapping 18
Get Data from a File 18
Save this Data in a File 25
Close Files without Exiting 25
Exit and Close All Files 25

4. Details Concerning Some of the Data Items 34

References 36

Appendices

A. Description of Input Data A-1
B. Data Forms B-1

FIGURES

Number		Page
1	ESP model data set used to initialize the data entry program	2
2	Main menu	6
3	Calculation parameters menu	7
4	Physical data menu	9
5	First particle size data menu	11
6	Second particle size data menu for size distributions calculated from mmd and σ	12
7	Second particle size data menu for size distributions where cumulative percent mass information is available	13
8	First sectional data menu	14
9	Continuation of first sectional data screen	15
10	Second sectional data screen (first field shown)	17
11	Sneakage and σ_g menu	19
12	Continuation of sneakage and σ_g menu	20
13	Opacity menu	21
14	Continuation of opacity menu	22
15	Rapping size distribution menu	23
16	Menu for opening a file to read data. The name of the file in this example is *filename*	24
17	Menu for reading additional data from a file which has been previously opened	26
18	Menu for opening a file so that an ESP data set can be saved. The name of the file in this example is *output.fil*	27
19	Menu for saving additional data in a previously opened file	28
20	When a file name is incorrectly specified, an error message will occur. In this case, an illegal comma was used in place of the period in the file name	29
21	Initial menu for the close files option	30

Figures (Cont.)

Number		Page
22	Continuation of the close files menu	31
23	Final close files menu	32
24	Example of a close files menu when no reading file was open	33
A-1	Flow chart for the input data logic	A-2

TABLES

Number		Page
1	Output Data Printed by the ESP MODEL	8
A-1	Opacity Related Input Data	A-10
A-2	Reduced Effective Negative Ion Mobilities for Various Gas Compositions	A-18
A-3	Values of Viscosity for Air at Various Temperatures and Water Contents	A-26
A-4	User Options when the Operating Voltage and Current are not Known	A-35

SECTION 1

INTRODUCTION

The computer model of electrostatic precipitator (ESP) performance (1) written by Southern Research Institute (SRI) for the Environmental Protection Agency (EPA) has undergone 3 revisions since it was first introduced. All versions of the ESP model require input data sets which are very exacting in the amount of data the user must furnish, the correctness of that data and the rigidity of the format in which the data sets must be written. An example of an ESP model data set is shown in Figure 1. The data are arranged in a very compact and nearly illegible pattern. An error in the location of a data item may make the data unreadable for the program, or worse, cause the model to read the data incorrectly and predict efficiency based on incorrect numbers.

Since the accuracy of the modeling depends on the quality of the data, little can be done to simplify the task of gathering good quality data for modeling. However, the task of putting that data into the required format is one that can be made user-friendly. SRI has written a program for IBM PC-compatible microcomputers which will greatly facilitate data entry, thereby eliminating one of the major sources of error in the use of the ESP model. This program has the following features:

1. The data are displayed in a set of menu-driven data forms.

2. Each data item is entered by typing the correct number in the space provided. Pressing an arrow moves the cursor to another item, pressing return moves the cursor to the next item, and pressing the escape key moves to another menu.

3. Each data item is identified by description (e.g. gas temperature). In addition, many of the data are identified by the variable name used in the model for reference to the input data instructions in Appendix A.

4. Data may be read from existing data files and either corrected or merged with other data to form a new data file.

5. When changing textual data, the operator may enter data in either the letter replacement mode or the letter insertion mode, as in a word processor.

6. The data files written by the program are in the standard ESP model data format and may be used by any EPA/SRI ESP model.

7. When the program begins, a set of ESP data will be displayed as a guide in selecting values of data for the application at hand. The data are for a hypothetical four section ESP having 9 in. plate spacing, a plate area of 27,000 ft^2 per section, and an SCA of 320 ft^2/kacfm. The particle size distribution is typical of ash created by burning pulverized bituminous coal (2). The electrical conditions were

```
19 1 0 0 015.00    0    0    0 8.00 3.50
TEST PLANT 2:  4 SECTION ESP WITH 320 SCA, BITUMINOUS COAL SIZE DISTRIBUTION
 1 2 11511 2 0 1 1 1 3
10
   2.000  36.000  99.900 2400.00  100.00    1.200.000270   1.000.15E+070.20E+11
0.050.15 4.00.100.25 4.00.000.00 4.0
   0.010   0.070   0.100   0.140   0.220   0.340   0.500   0.700   1.000  1.400
   2.200   3.400   5.000   7.000  10.000  14.000  22.000  34.000 100.000
  16.300   3.400
 410101010
 2.7000E+04 4.3100E+04 4.9000E-01 2.7000E+04 7.5000E-02 4.5000E+00 1.8000E+01
 3.0000E+00 3.3750E+05 5.0000E+00 3.0000E+02 1.0000E+00 2.3000E-05 9.0000E-01
 2.7000E+04 4.2000E+04 7.3700E-01 2.7000E+04 7.5000E-02 4.5000E+00 1.8000E+01
 3.0000E+00 3.3750E+05 5.0000E+00 3.0000E+02 1.0000E+00 2.3000E-05 9.0000E-01
 2.7000E+04 3.9800E+04 7.4800E-01 2.7000E+04 7.5000E-02 4.5000E+00 1.8000E+01
 3.0000E+00 3.3750E+05 5.0000E+00 3.0000E+02 1.0000E+00 2.3000E-05 9.0000E-01
 2.7000E+04 3.8200E+04 9.3100E-01 2.7000E+04 7.5000E-02 4.5000E+00 1.8000E+01
 3.0000E+00 3.3750E+05 5.0000E+00 3.0000E+02 1.0000E+00 2.3000E-05 9.0000E-01
99
```

Figure 1. ESP model data set used to initialize the data entry program.

obtained from the SRI-EPRI correlation of operating conditions (2). The start-up data file is named INITIAL.DAT and is the data set shown in Figure 1. If a different start-up data set is desired, it is only necessary to name the file INITIAL.DAT to make the change.

A detailed description of the use of each of the data menus is given in Section 3. Section 4 discusses those cases in which the data that appear in this program do not correspond exactly to the data that appear in ESP model data sets. Appendix A contains a complete listing of ESP model input data, extracted from the report for revision 3 of the ESP model (1). Appendix B contains data forms which mimic the data screens used in this program. These forms may be useful in organizing ESP data before using this program.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

This report describes the operation of a program that greatly simplifies the creation and modification of data files for use with the ESP model. This program, which is written for IBM PC-compatible computers, displays the data in a series of menus and allows the user direct access to the displayed data. After the user has typed the data into the menus, the program will make any necessary calculations and then store the data in a file in the correct format for reading by the ESP model. This program will also read existing ESP model files so that data files may be corrected, modified, or combined.

The data files written by this program are in ASCII format with the required record length of 80 characters. When a file is displayed on a screen, lines that take the full 80 characters may wrap around to the next line. This is the result of the video screen allowing too few characters per line and may be avoided by looking at the file through an editor.

As with all programs of this type, familiarity comes through use. The program is easy to use and forgiving of mistakes. It should be of great value to ESP model users as a means of entering error-free data in a minimum of time. Data files written by this program on a microcomputer may also be transferred to a main-frame computer without changes.

SECTION 3

USE OF THE DATA ENTRY FORMS

The data entry program is written in compiled Microsoft QuickBASIC for IBM PC-compatible microcomputers. The following files must be present for the program to work:

1. DATA.EXE - the compiled program, and
2. INITIAL.DAT - the startup data set.

To begin the data entry routine, type DATA and press the enter key. After the program loads, the screen will show the main menu shown in Figure 2. In this menu, the data are broken down into 5 categories, each with its own sub-menu. Following the data categories, there are 4 file-handling functions. The arrows move the cursor up or down to the desired data category or file-handling function. Pressing the escape key (ESC) or the enter/return key then shifts the screen to the chosen sub-menu or begins the function. The operation of each item on the main menu is discussed below.

CALCULATION PARAMETERS

The calculation parameters screen is shown in Figure 3. Either upper or lower case letters may be used for the textual data. The letters REP on the lower left edge of the screen indicate that the text is being entered in the replacement mode, in which the existing letters are written over without changing their locations. If the insert key is pressed, text entry is made in the insertion mode, in which existing text is moved to the right as new letters are typed. In this mode, the letters INS will be displayed on the lower left. The replacement mode is required when entering text where there is space for only one letter, such as the cold or hot side choice.

The calculation parameters menu allows the user to choose the amount of output data which will be written to the output data file. Table 1 summarizes the printing options which are available. The user also has a choice of using fast but less accurate estimations or slower, more accurate rigorous calculations for the particle charge and collection electric field. The estimations are usually adequate for operation or design change exploration, but the rigorous calculations should be used before any results are used in critical applications. The user may also choose rapping corrections which are appropriate for cold or hot side ESPs.

It is necessary for the user to supply an estimated efficiency so that the model can form an initial estimate of the space charge in the ESP. A close estimate may reduce the run time of the ESP model.

PHYSICAL DATA

The physical data screen is shown in Figure 4. The information on the screen is arranged into four columns. The first column contains a description of each data item. The second column gives the FORTRAN name of each item for reference to the data listing in Appendix A. The third column contains the data value, and the forth column contains the units for each item.

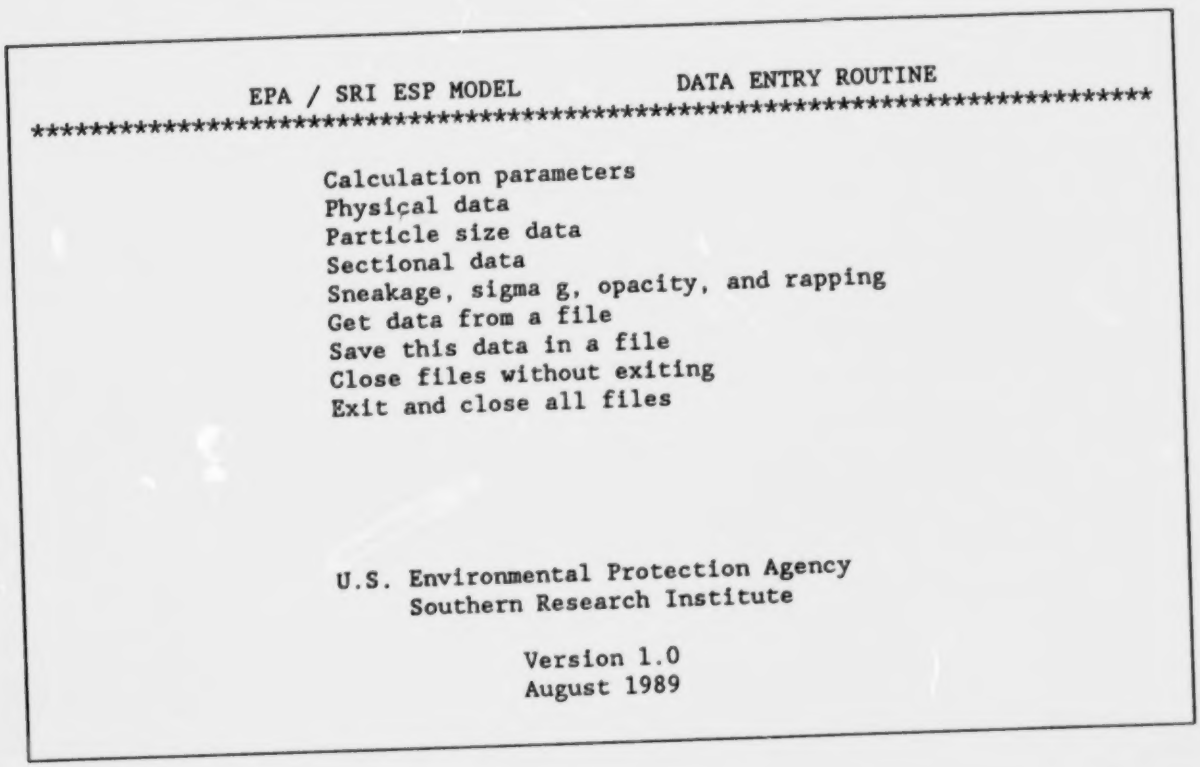


Figure 2. Main menu.

```
                              CALCULATION PARAMETERS
*******************************************************************************

Title:
TEST PLANT 2:  4 SECTION ESP WITH 320 SCA, BITUMINOUS COAL SIZE DISTRIBUTION

Amount of printing [-1 most, 0 standard, 1 less, 2 least]      0
Estimations (fast) or Rigorous calculations (slow) [E or R]    R
Cold side or Hot side [C or H]                                 C

Estimated efficiency                                          99.9    %




REP

                          Use ESC to return to main menu
```

Figure 3. Calculation parameters menu.

Table 1

OUTPUT DATA PRINTED BY THE ESP MODEL

Data printed	Value of Amount-of-Printing Variable			
	-1	0	1	2
Input Data	X	X	X	X
ESP Analysis by Increment	X	X	X	-
Voltage, Electric Field, and Space Charge Map	X	-	-	-
Particulate Charge Summary	X	X	-	-
Performance Analysis by Size Bands	X	X	X	X
Opacity Analysis by Size Bands	X	X	-	-
Opacity Summary	X	X	X	X
Performance Summary Block	X	X	X	X

PHYSICAL DATA

****

Inlet mass loading	DL	2.00	gr/acf
Particle density	DD	2400.	kg/m3
Ash resistivity (capital E)	RHO	2.00E+10	ohm-cm
Percent water	PCH2O	8.00	%
Percent oxygen	PCO2	3.50	%
Ion mobility (typically .00027)	US	0.00027	m2/V/s
Dielectric ratio (typically 100)	EPS	100.0	
Peak-to-average voltage ratio (typically 1.2)	VRATIO	1.2	

Use ESC to return to main menu

Figure 4. Physical data menu.

These data are arranged into two groups. The first group contains frequently changed data. These data are entered as decimal numbers except for the resistivity, which is entered as an exponential number. When entering an exponential number, a capital E must be used. A lower case e will not be recognized and may lead to run-time errors. In general, any number may be entered as an exponential number but unless the display calls for an exponential number, the number will not be shown correctly until it is completely entered. This may cause the operator to make data entry errors. It is best to enter numbers using the same format shown on the screen.

The data in the second group contain values that are typical of many power plant applications. These data may be changed if more accurate numbers are known. However, in the absence of better data, these data may be used with good results.

PARTICLE SIZE DATA

The ESP model compensates for the different charging and collecting rates of large and small particles by dividing the particle size distribution into narrow size bands. A series of menus allows the user to define the size bands by specifying the end points of each band. The first particle size data menu is shown in Figure 5. The number of size band end points and the type of size data entered in this menu determine the layout of the next screen. The values shown in the figure are for 19 end points with log-normal size data (mmd and σ). Figure 6 shows the second data menu for this choice. The first two values on the screen are the mmd and σ of the size distribution. The next 19 values are the size band end points. In choosing values for end points, it is recommended that more end points be used at the fine particle end of the distribution, because these values are more critical to the performance of the ESP.

If the type of size data is changed to cumulative percent mass (NDIST = 1 in Figure 5), the second size data screen will look like the one in Figure 7. (The values of cumulative percent are all zeros because there were no cumulative percent data in the initialization data set.) On this screen, the left and right arrows are used to change between the data columns. The up and down arrows move the cursor up and down within a column. Note that the first cumulative percent must be 0 and the last must be 100.

SECTIONAL DATA

This series of menus is used to enter the data that change with each ESP field over the length of the ESP. The first menu, shown in Figure 8, asks how many fields will be entered. For the ESP model, the word field refers to separately electrified sections in the direction of gas flow. Side-by-side fields (across the gas flow) are treated as a single field by the model. According to Figure 8, the ESP used to initialize the model has four fields in the gas flow direction.

Figure 9 shows the continuation of the first data screen. Additional data forms have been added to the bottom of the screen shown in Figure 8. The data entered into this screen are the length of each electrified field, and the number of calculation length increments that each field will be divided into. Each field should be divided into length increments approximately 1 ft. long so

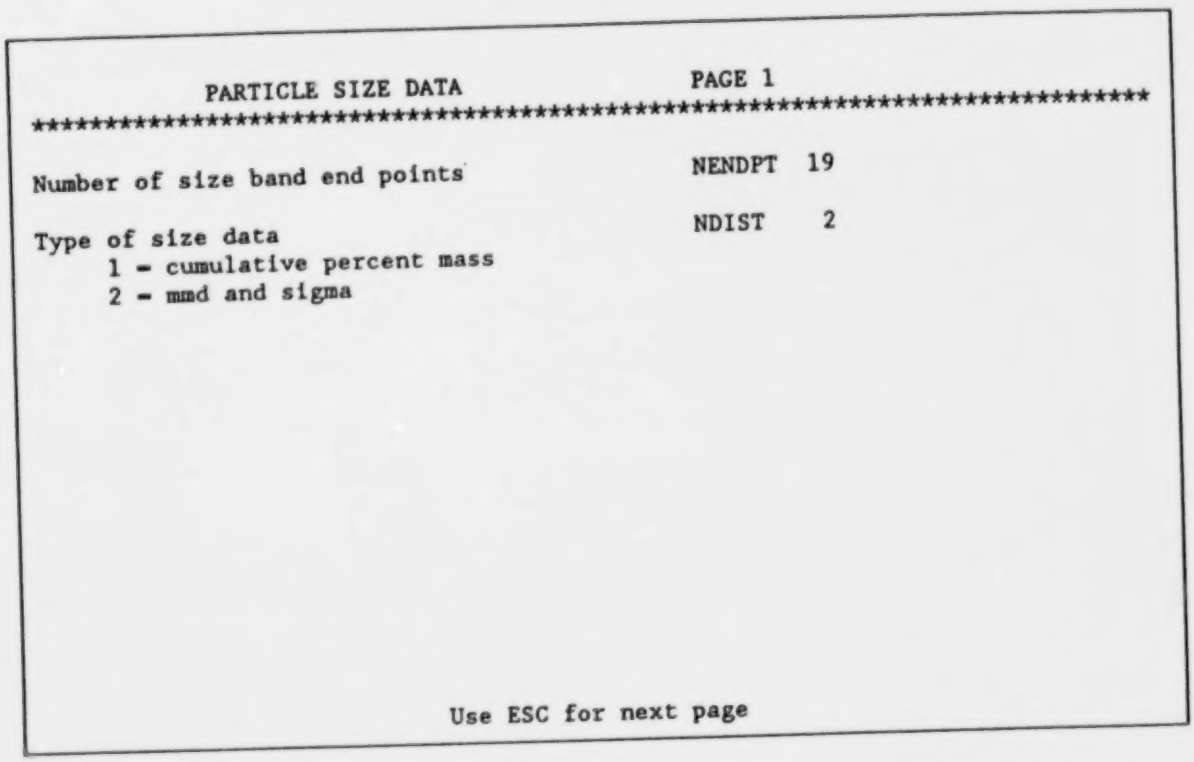


Figure 5. First particle size data menu.

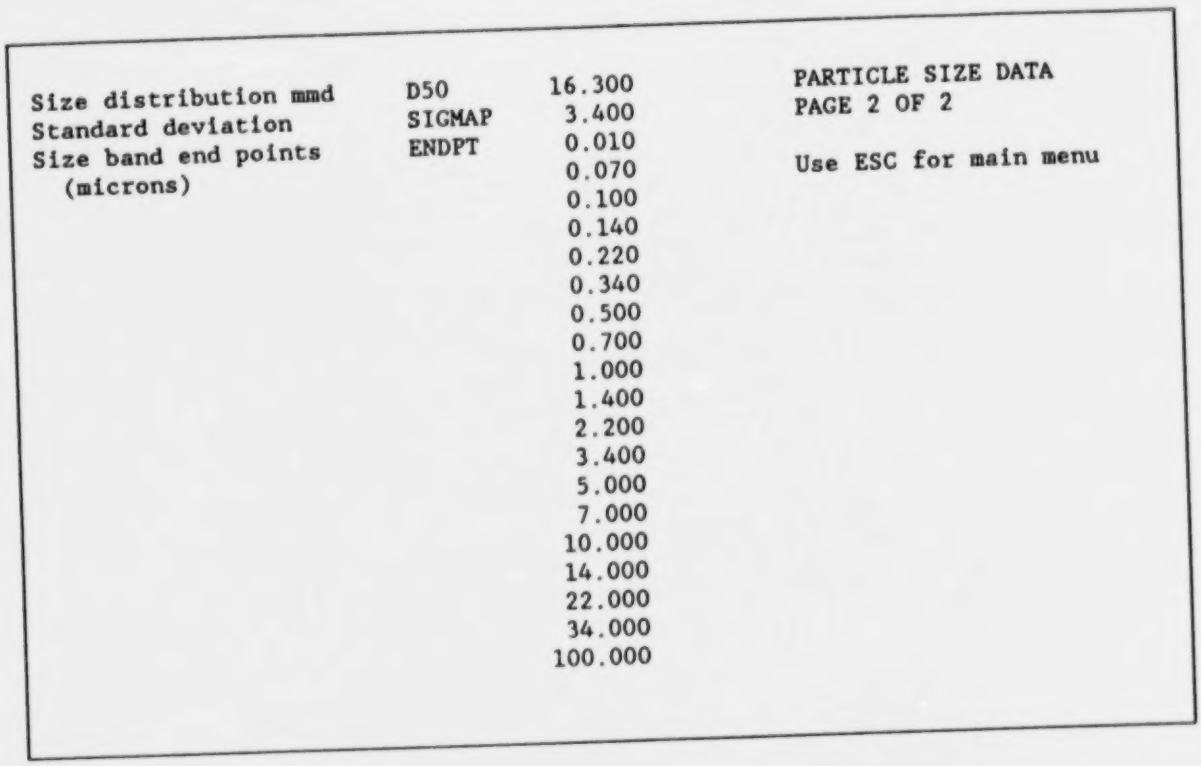


Figure 6. Second particle size data menu for size distributions calculated from mmd and σ.

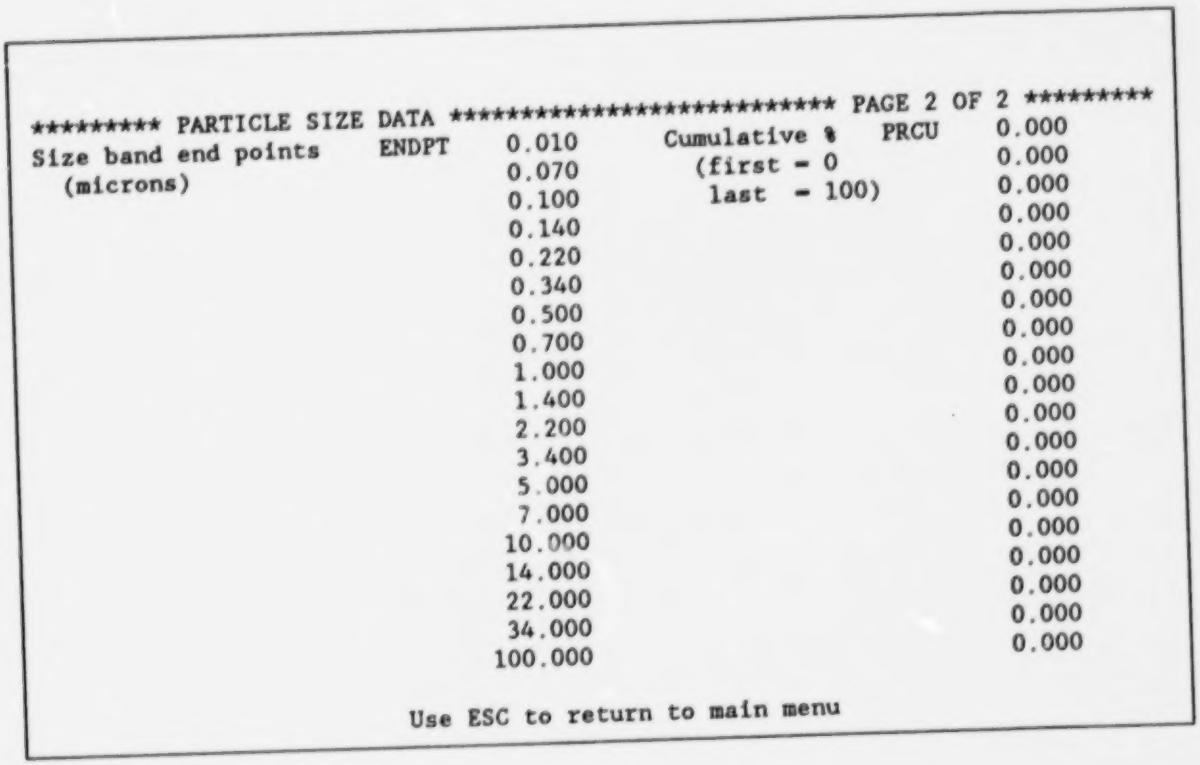


Figure 7. Second particle size data menu for size distributions where cumulative percent mass information is available.

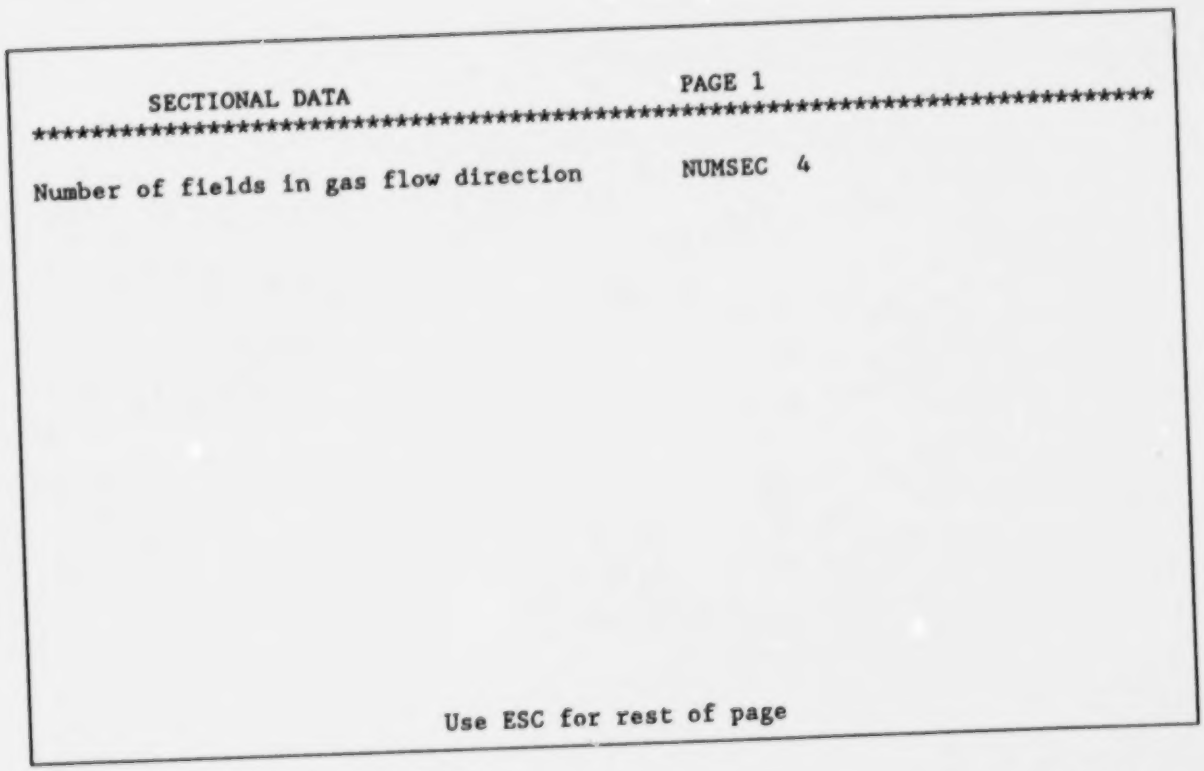


Figure 8. First sectional data menu.

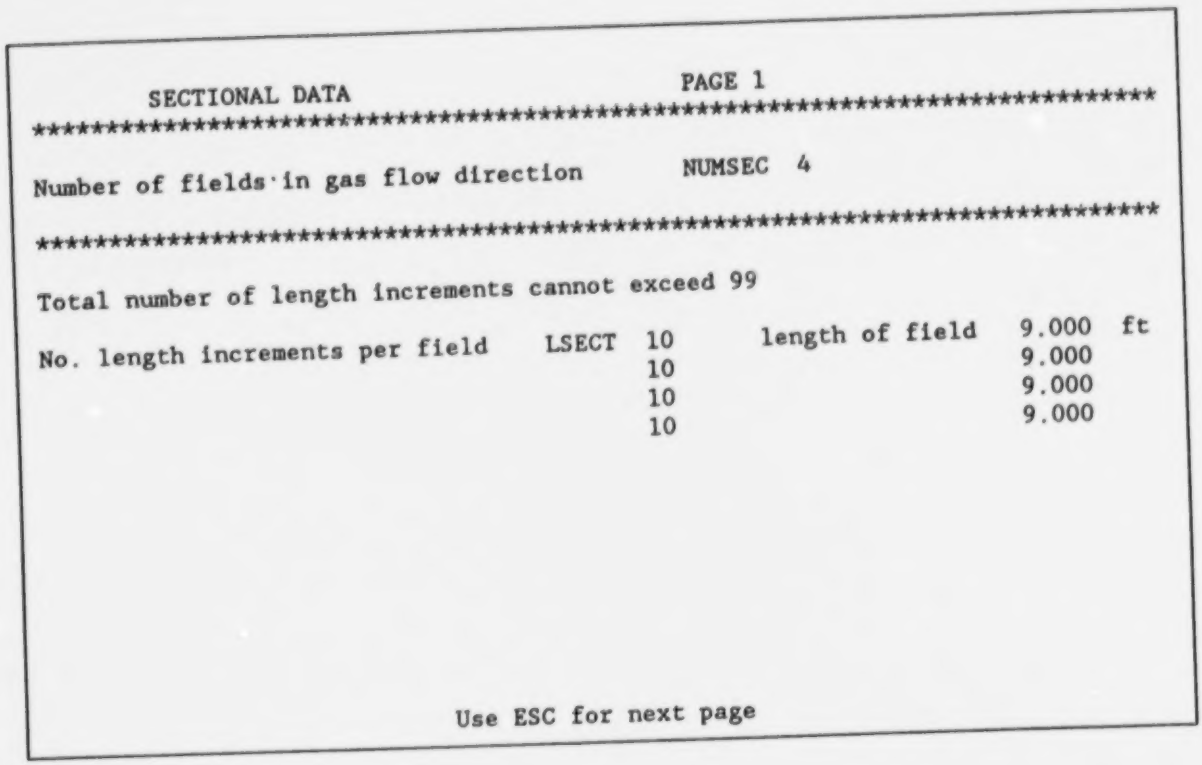


Figure 9. Continuation of first sectional data screen.

that the model can track the changing conditions within the ESP. Shorter increments result in a more accurate, but more time consuming, calculation. In the data in Figure 9, each 9-ft field is divided into 10 length increments. As previously stated, cursor movement between the columns is provided by the left and right arrows.

Figure 10 shows an example of the second sectional data screen. There will be one of these screens for each field in the gas flow direction as specified in the screen in Figure 8. The following data are entered in this menu.

Voltage	- the voltage is averaged over any parallel fields
Current	- the total current is summed over any parallel fields
Plate area	- the total area is summed over any parallel fields
Total wire length	- the length is summed over all parallel lanes
Corona wire radius	
No. of wires per lane	- the value for the number of wires per lane should not exceed 20
Wire-to-plate spacing	- if the spacing is not uniform, the closest value is usually used
Wire-to-wire spacing	- if the spacing is not uniform, the average value is usually used
Gas volume flow rate	- the total gas flow rate through the ESP
Gas velocity	- the gas velocity within the ESP
Gas temperature	- the gas temperature within the ESP
Gas pressure	- refers to the pressure within the ESP

Below the data list, 2 lines show the specific collection area (SCA) and current density calculated from the data on the screen. These quantities are recalculated each time the values from which they are derived are changed. Another calculated quantity is the gas velocity. If the calculated velocity differs from the user-input value by more than 5%, a warning message stating that the gas velocity and volume are inconsistent appears to the right of the data field. This message will disappear when the inconsistency is removed by entering the correct data. The gas velocity is calculated according to the following equation:

$$V = \frac{L\,Q}{5\,S\,A}$$

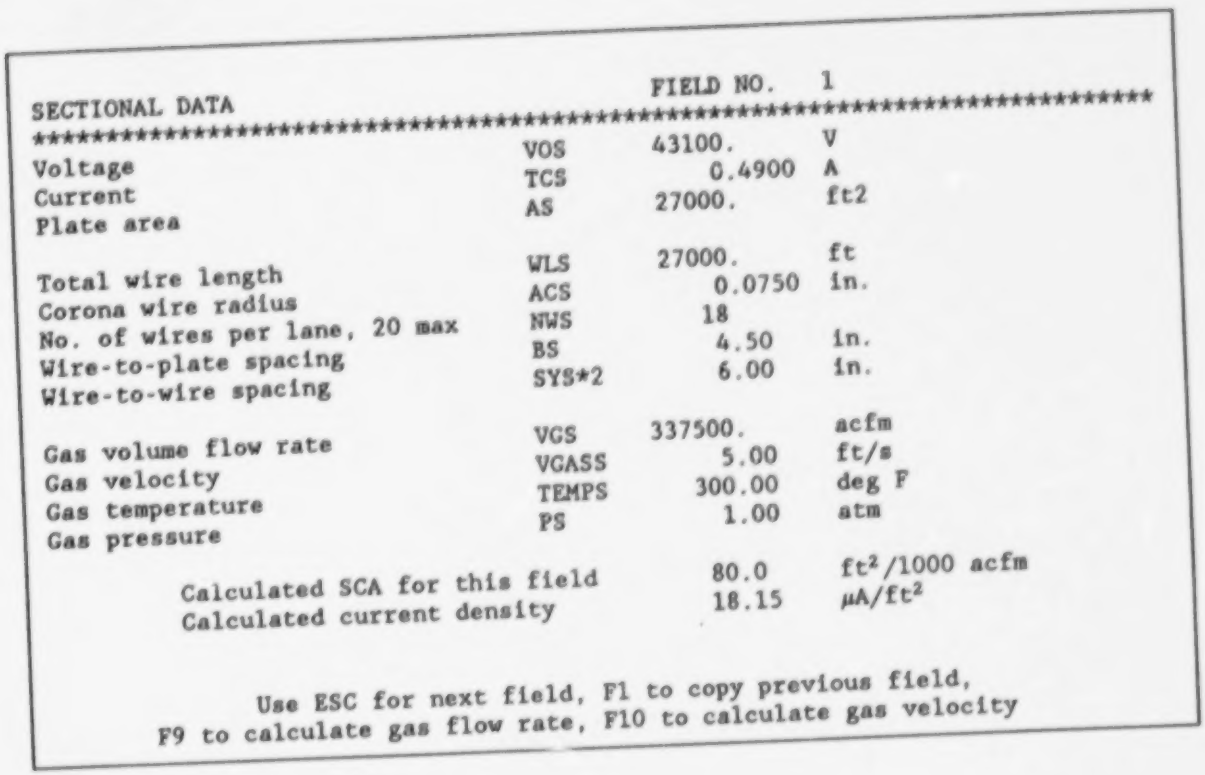

SECTIONAL DATA
FIELD NO. 1
Voltage VOS 43100. V
Current TCS 0.4900 A
Plate area AS 27000. ft2
Total wire length WLS 27000. ft
Corona wire radius ACS 0.0750 in.
No. of wires per lane, 20 max NWS 18
Wire-to-plate spacing BS 4.50 in.
Wire-to-wire spacing SYS*2 6.00 in.
Gas volume flow rate VGS 337500. acfm
Gas velocity VGASS 5.00 ft/s
Gas temperature TEMPS 300.00 deg F
Gas pressure PS 1.00 atm
Calculated SCA for this field 80.0 ft²/1000 acfm
Calculated current density 18.15 μA/ft²
Use ESC for next field, F1 to copy previous field,
F9 to calculate gas flow rate, F10 to calculate gas velocity

Figure 10. Second sectional data screen (first field shown).

in which V is the gas velocity in ft/s, L is the plate length in ft, Q is the gas flow rate in acfm, S is the wire-to-plate spacing in in., and A is the plate area in ft^2. This equation is for straight wires in the center of the lane and uniform flat plates. Other geometries may require gas velocity and flow rate values that are inconsistent according to this equation, in which case the warning message should be ignored.

At the bottom of the screen, the user is given the options of copying the data from the previous field, of calculating the gas flow rate from the gas velocity, and of calculating the gas velocity from the gas flow rate. If the first field data has been entered and subsequent fields are similar to the first, it is usually quicker to copy the first field and then change the data that are different than to reenter all of the data. The calculations use the gas velocity equation from the preceding paragraph and apply only to straight-wire flat-plate ESPs.

SNEAKAGE, SIGMA G, OPACITY, AND RAPPING

The first screen in this group of data screens requests the number of non-ideal-gas-flow data sets the user wants to enter. This screen is shown in Figure 11. When the user enters the data and presses ESC, additional data are added to the screen as shown in Figure 12. In this additional data, the sneakage fraction is that portion of gas which flows around the electrified region of the ESP and avoids the charging and collection process. The gas velocity σ is the standard deviation of the gas velocity distribution across the ESP. The number of baffles refers to the number of baffles that force the sneakage gas to remix before entering the next field.

The first part of the opacity menu is shown in Figure 13. The REP in the lower left corner refers to the text replacement mode, which is appropriate for entry of a single letter. If "yes" is chosen in Figure 13, pressing ESC will add the line requesting opacity path length, as shown in Figure 14. If "no" is chosen, the screen in Figure 14 will not appear and a value of 0 will be used for the opacity path length.

Following the opacity menu, the rapping menu will be displayed. As shown in Figure 15, the first rapping data set is built into the model. If a different data set is desired, enter a number greater than 1 for the number of rapping size distributions. When ESC is pressed, a form for N - 1 additional rapping mmd and σ values will be added to the bottom of this screen for entry of the additional values.

GET DATA FROM A FILE

When this option is chosen, the program will read existing data from a data file so that the user can make changes or merge the data with other data sets. Figure 16 shows the screen which requests the name of the data file from which to read the data. The user enters a valid file name (which under DOS can have up to 8 characters followed by a period and an extension of up to 3 characters) and presses "enter". The program will then read the first data set in the file and will make the data available for display in the various menus. If there is only one data set in the file, the message

FINAL DATA SET IN FILE - CLOSE FILE

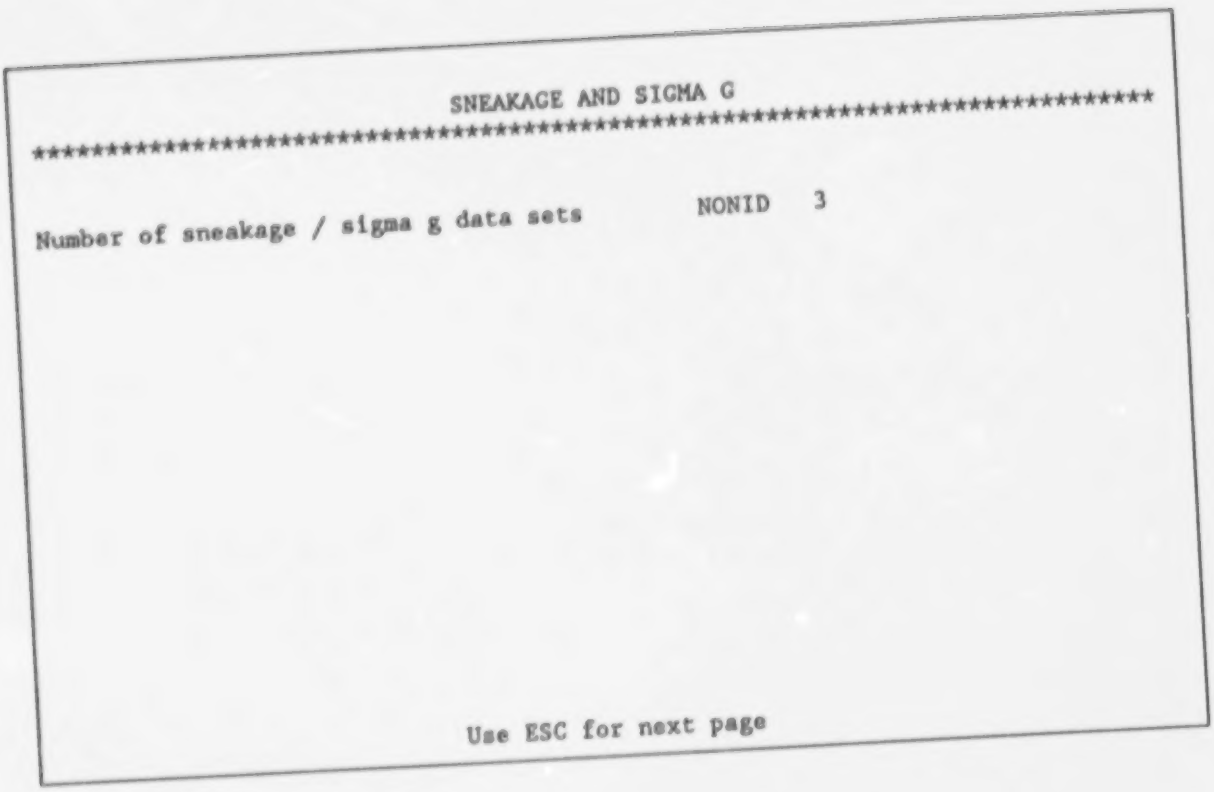


Figure 11. Sneakage and σ_s menu.

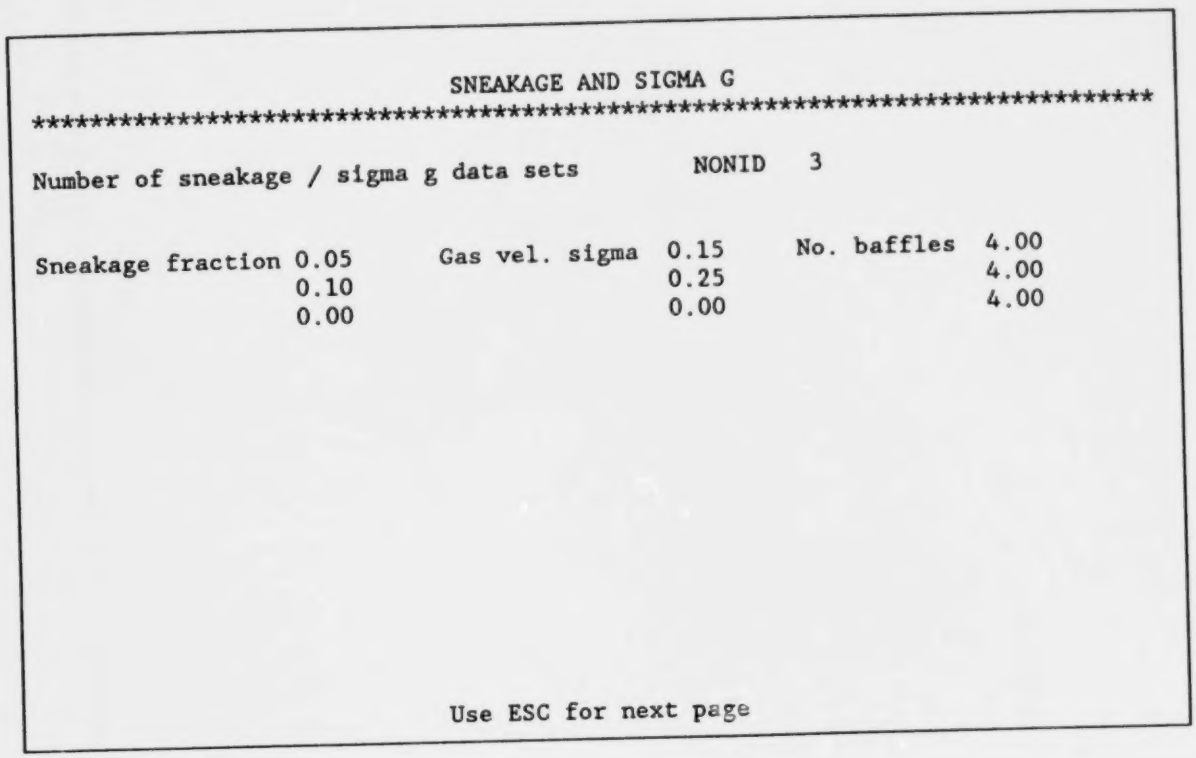


Figure 12. Continuation of sneakage and σ_g menu.

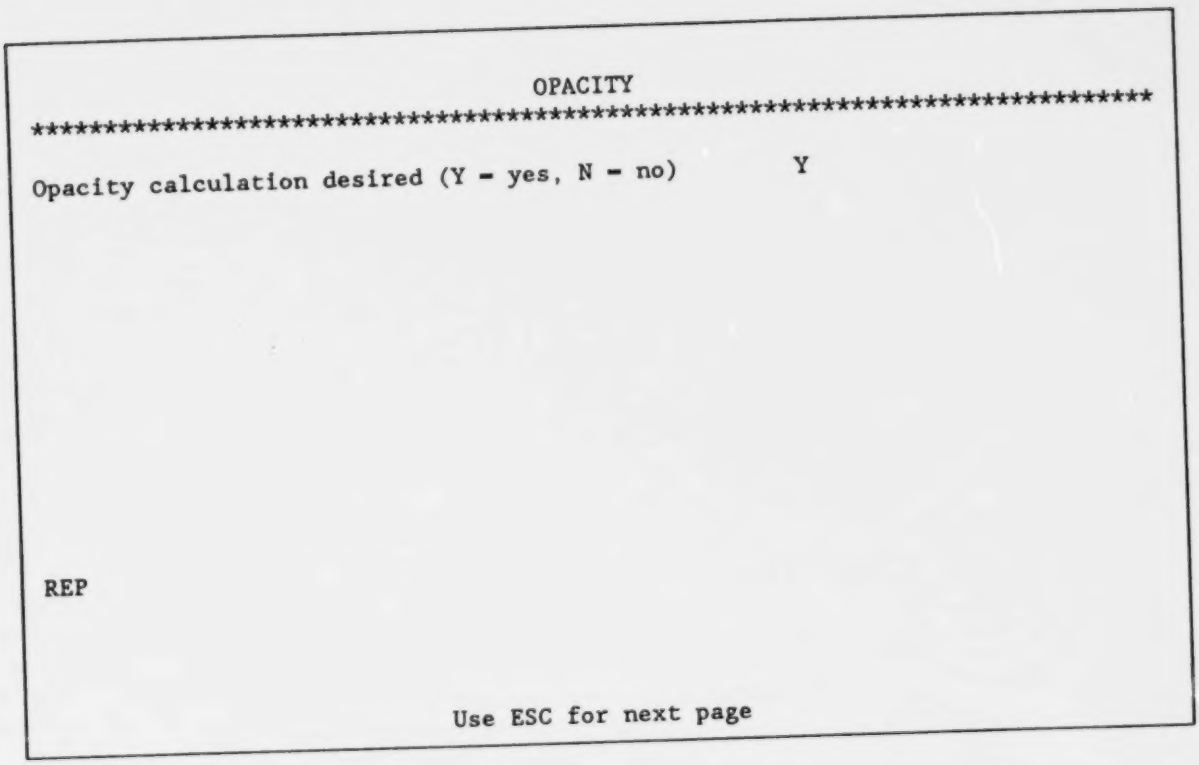


Figure 13. Opacity menu.

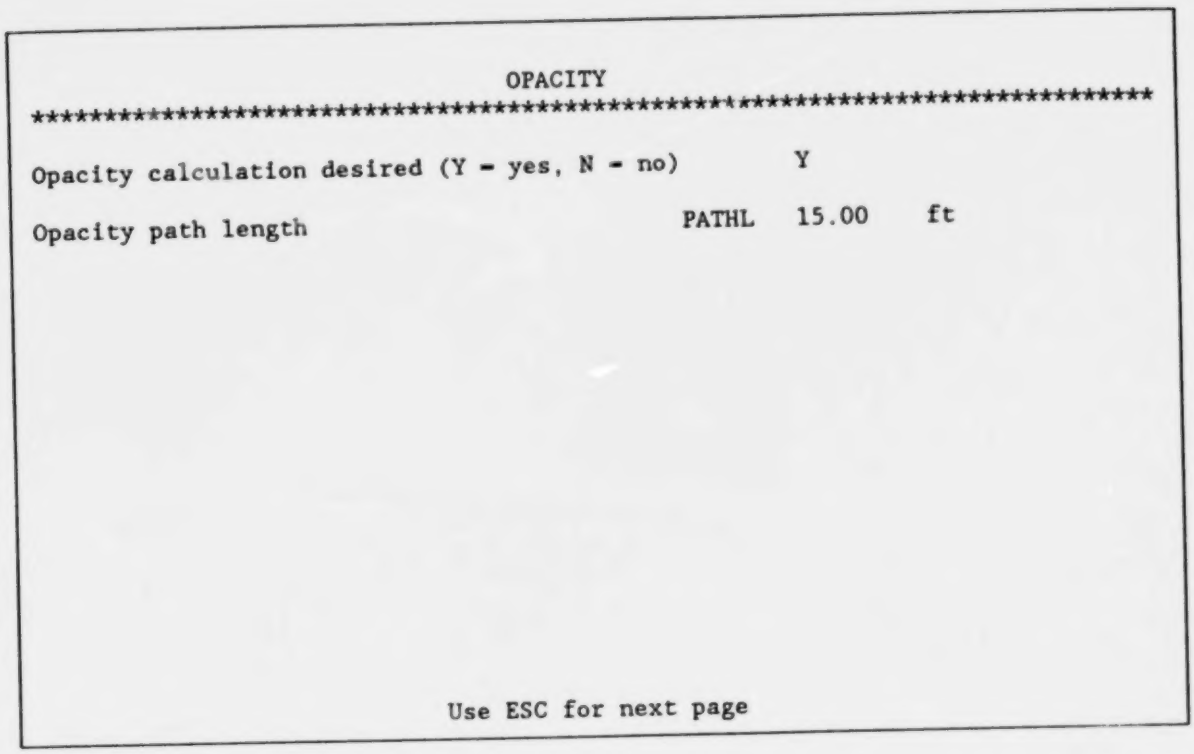


Figure 14. Continuation of opacity menu.

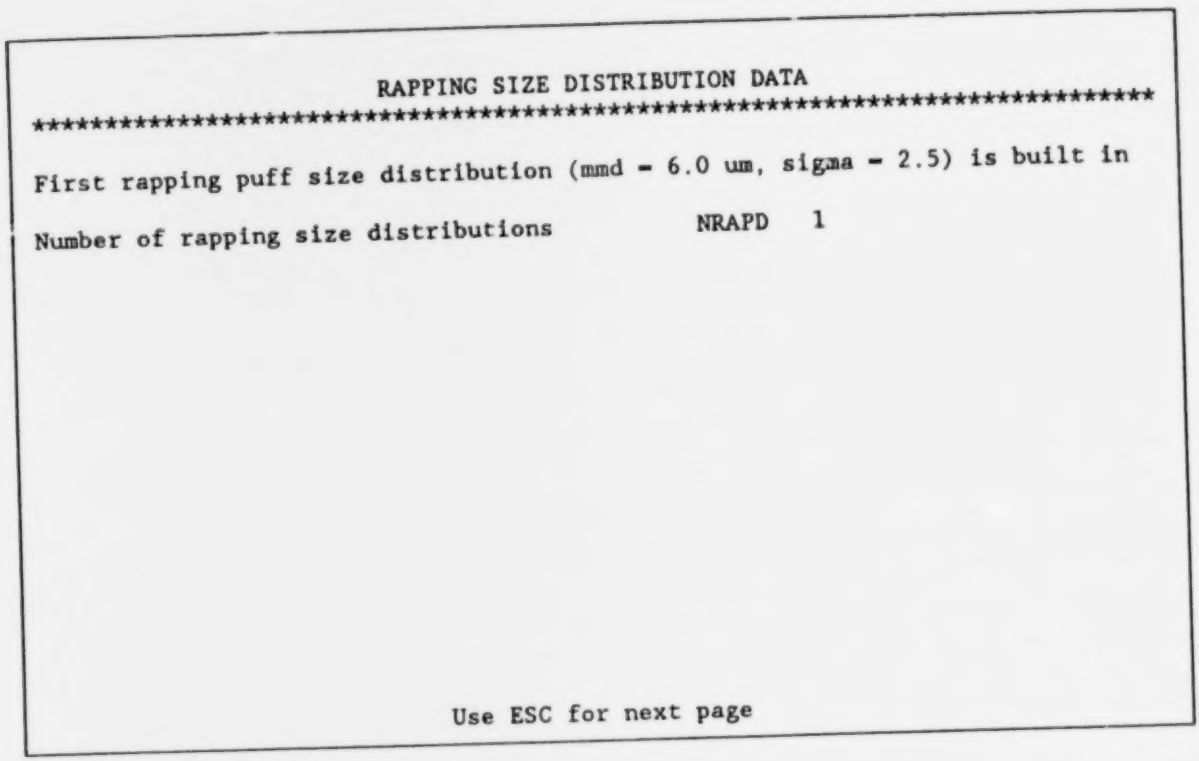

RAPPING SIZE DISTRIBUTION DATA
First rapping puff size distribution (mmd = 6.0 um, sigma = 2.5) is built in
Number of rapping size distributions NRAPD 1
Use ESC for next page

Figure 15. Rapping size distribution menu.

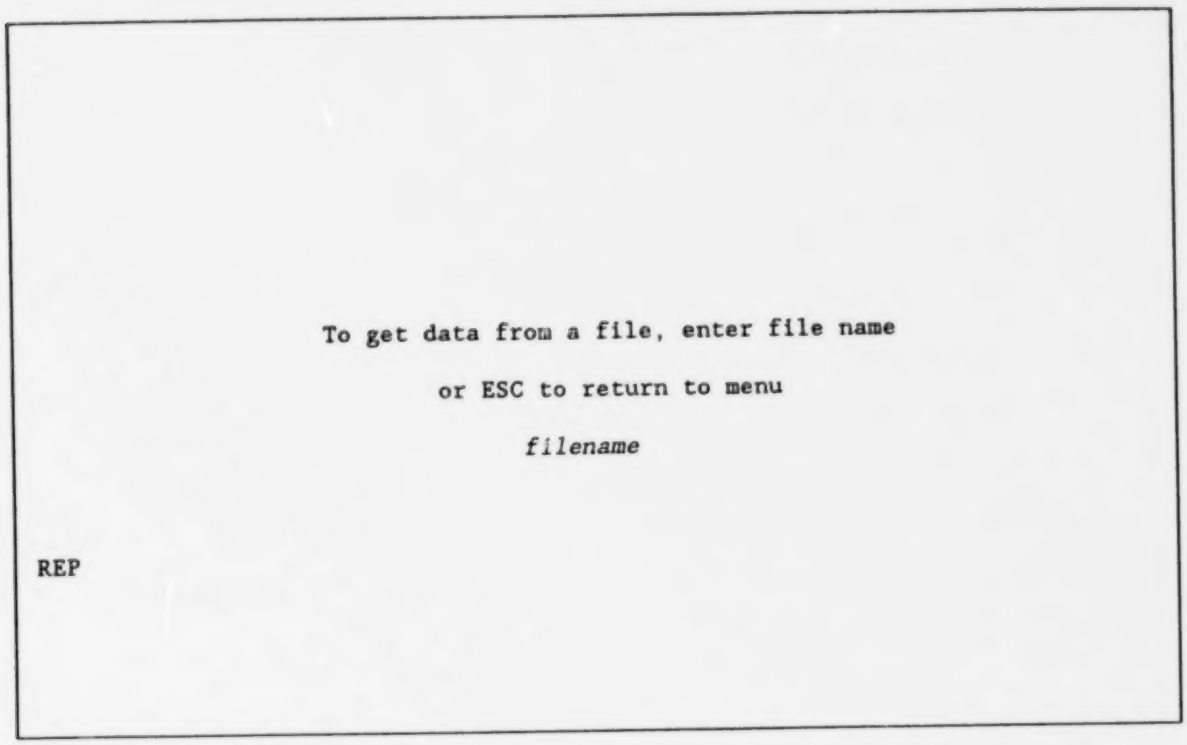


Figure 16. Menu for opening a file to read data. The name of the file in this example is *filename*.

will appear briefly on the screen and the file will be closed. If there is more than one data set in the file, the file will remain open so that more data may be read from it. The program will then return to the main menu (Figure 2).

Figure 17 shows the screen that will appear when "Get data from a file" is chosen and a file is already open for reading. The first two lines verify that the user did mean to read additional data. If this option was chosen in error, press N or ESC to return to the main menu without reading additional data. If Y is chosen, the program will read additional data, which will replace any existing data in the program. If the previous data have not been saved, they will be lost when new data are read. If the newly read data comprise the last data set in the file, the "FINAL DATA SET - CLOSE FILE" message will appear on the screen. Otherwise, the file will be left open for further reading. The program then returns to the main menu.

SAVE THIS DATA IN A FILE

The procedure for writing data into a file is similar to that for reading data. The data screens are shown in Figures 18 - 20. After the data set is written, the file is left open so that additional data sets can be appended. The file is closed automatically when the program is exited, or it can be closed without exiting by selecting the "Close files without exiting" option.

Figure 20 shows an error message which can occur when an improper file operation is attempted, both in reading and writing. When the message appears, one has the option of trying again or quitting the read/write option and returning to the main menu using the ESC key.

CLOSE FILES WITHOUT EXITING

Figures 21 - 24 show the screens that can occur when the close files option is selected. If the program is being quit, it is not necessary to use this option to manually close any open files. All files are automatically closed when the program is exited. In general, this option will be used only when data are being written into more than one file or when data are being combined from more than one file.

In using this option, if a file is open, the program will identify the file by name and will check with the user before closing it (Figure 21). If N is entered, no action will be taken. If Y is entered, the file is closed and a message stating that the file is closed will be displayed (Figure 22). If the reading or writing file is not open, a message stating that the file is not open will be displayed (Figure 24).

EXIT AND CLOSE ALL FILES

This option ends the data entry program, closes any open files, and returns control to the computer's operating system or menu program if one is in use. Any data that have not been saved to a file are lost upon exiting and cannot be retrieved.

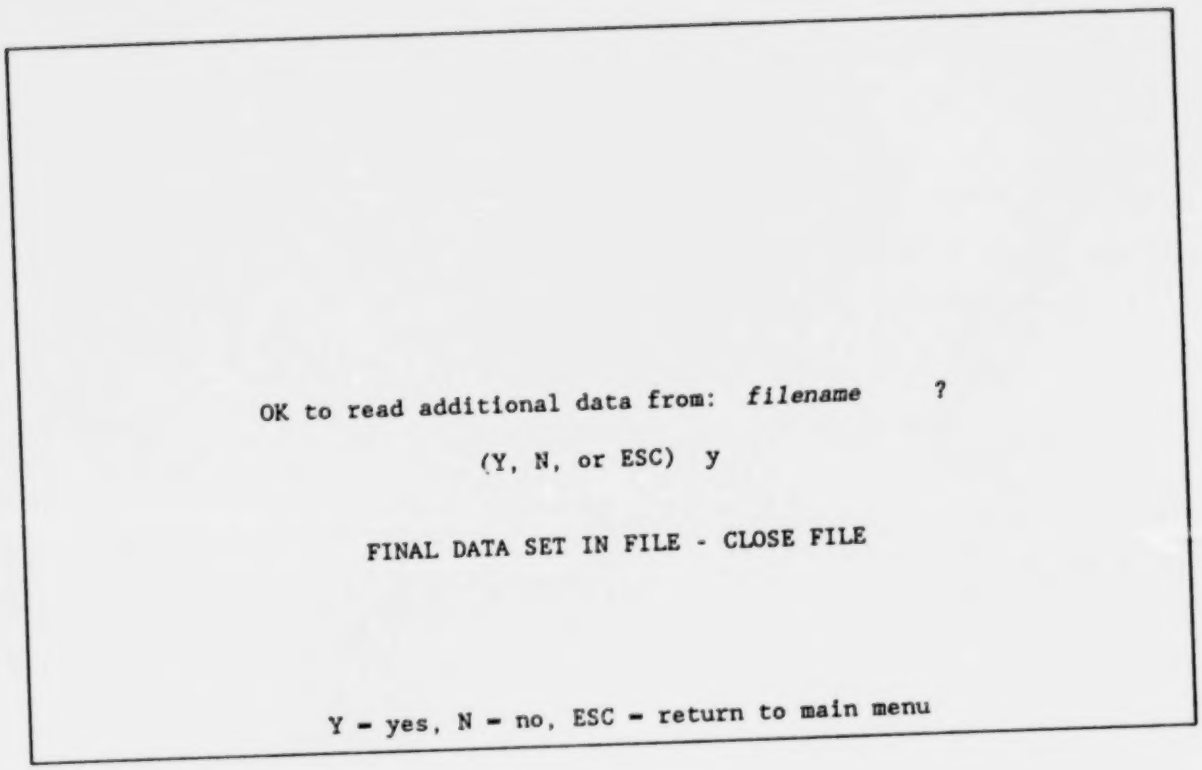


Figure 17. Menu for reading additional data from a file which has been previously opened.

Figure 18. Menu for opening a file so that an ESP data set can be saved. The name of the file in this example is *output.fil*.

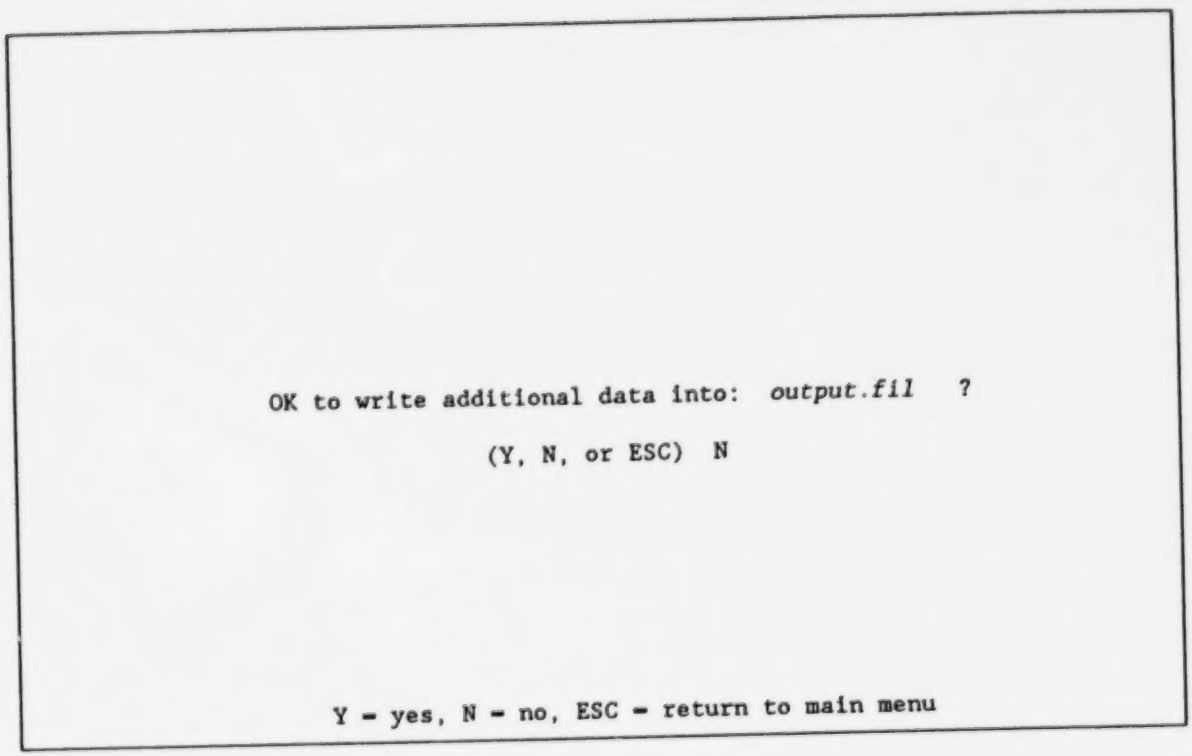


Figure 19. Menu for saving additional data in a previously opened file.

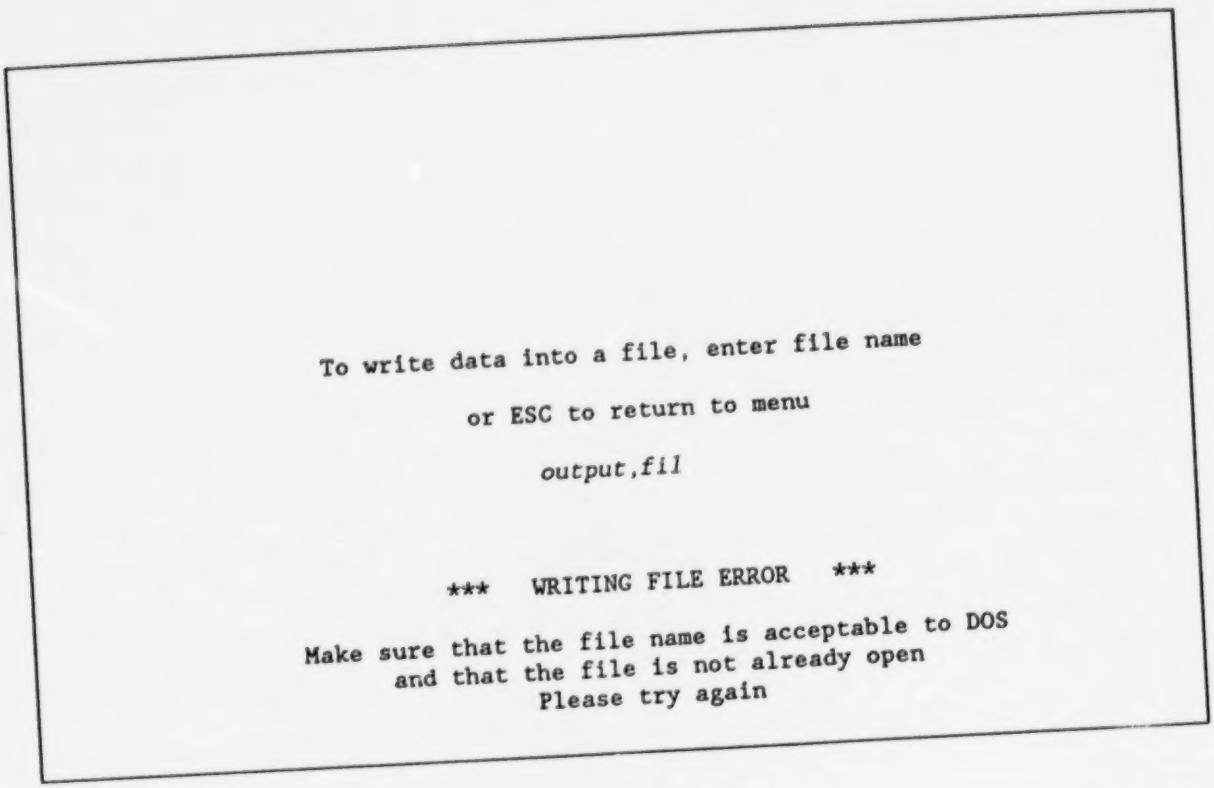

To write data into a file, enter file name
or ESC to return to menu
output,fil
*** WRITING FILE ERROR ***
Make sure that the file name is acceptable to DOS
and that the file is not already open
Please try again

Figure 20. When a file name is incorrectly specified, an error message will occur. In this case, an illegal comma was used in place of the period in the file name.

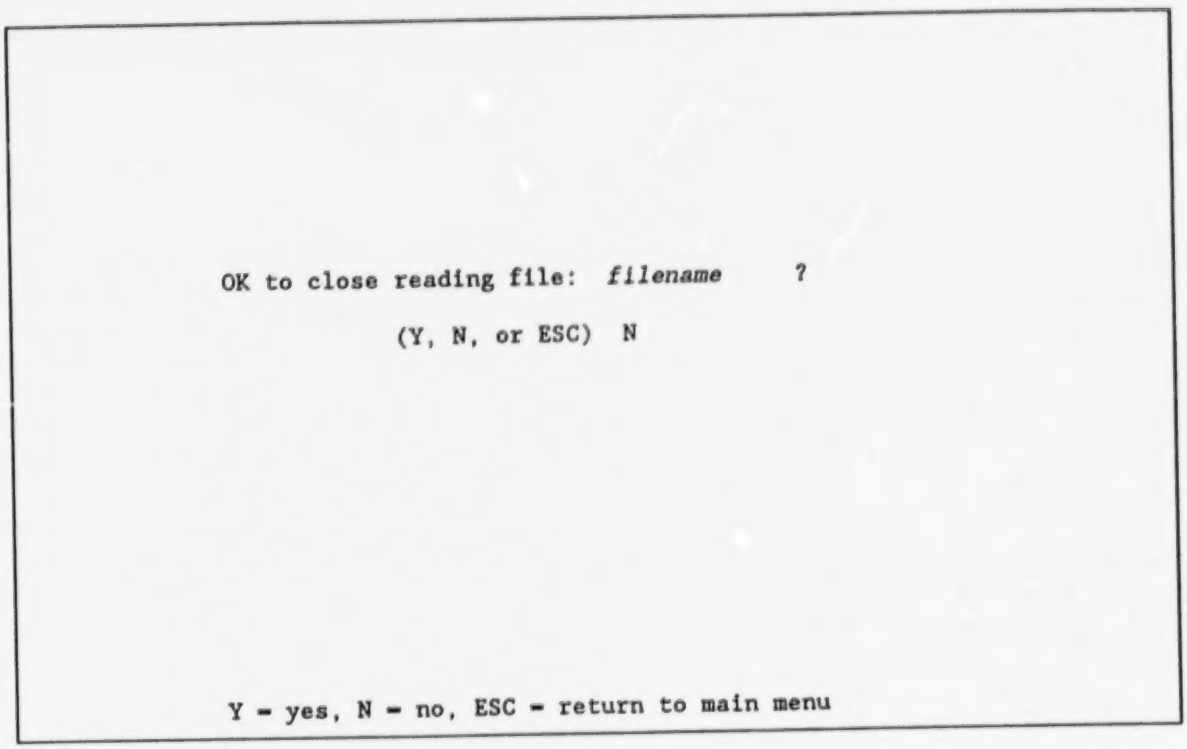


Figure 21. Initial menu for the close files option.

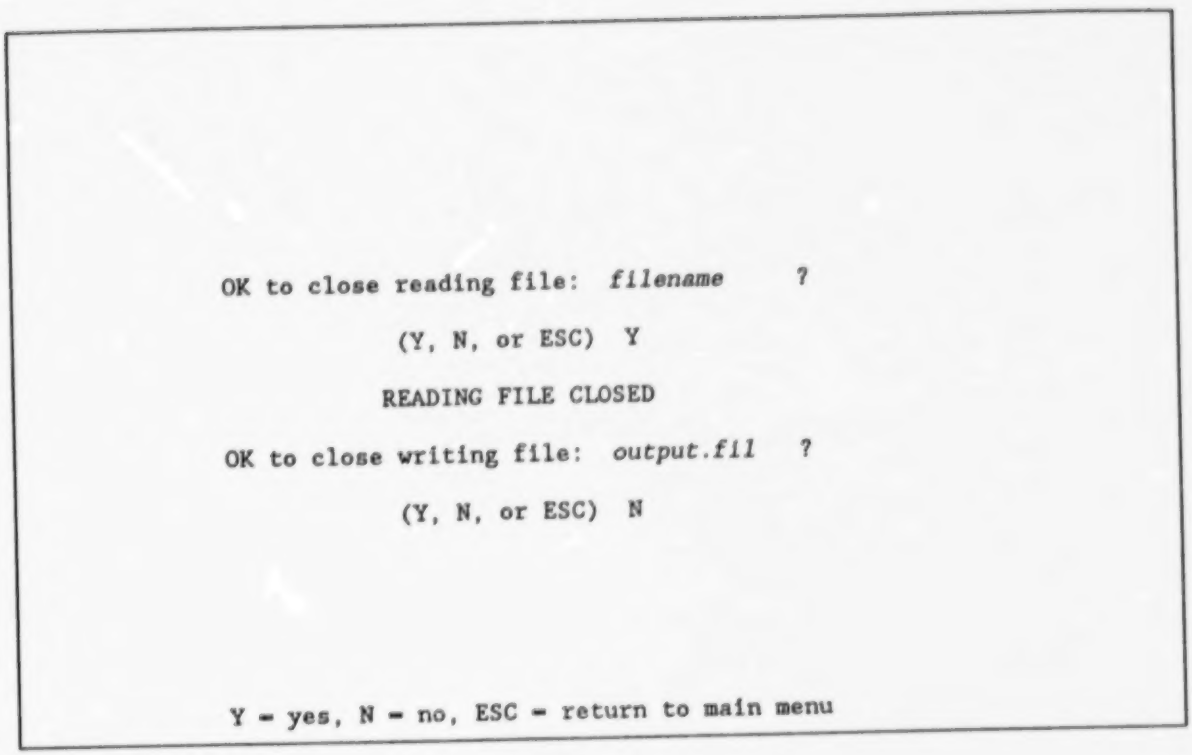

OK to close reading file: filename ?
(Y, N, or ESC) Y
READING FILE CLOSED
OK to close writing file: output.fil ?
(Y, N, or ESC) N
Y = yes, N = no, ESC = return to main menu

Figure 22. Continuation of the close files menu.

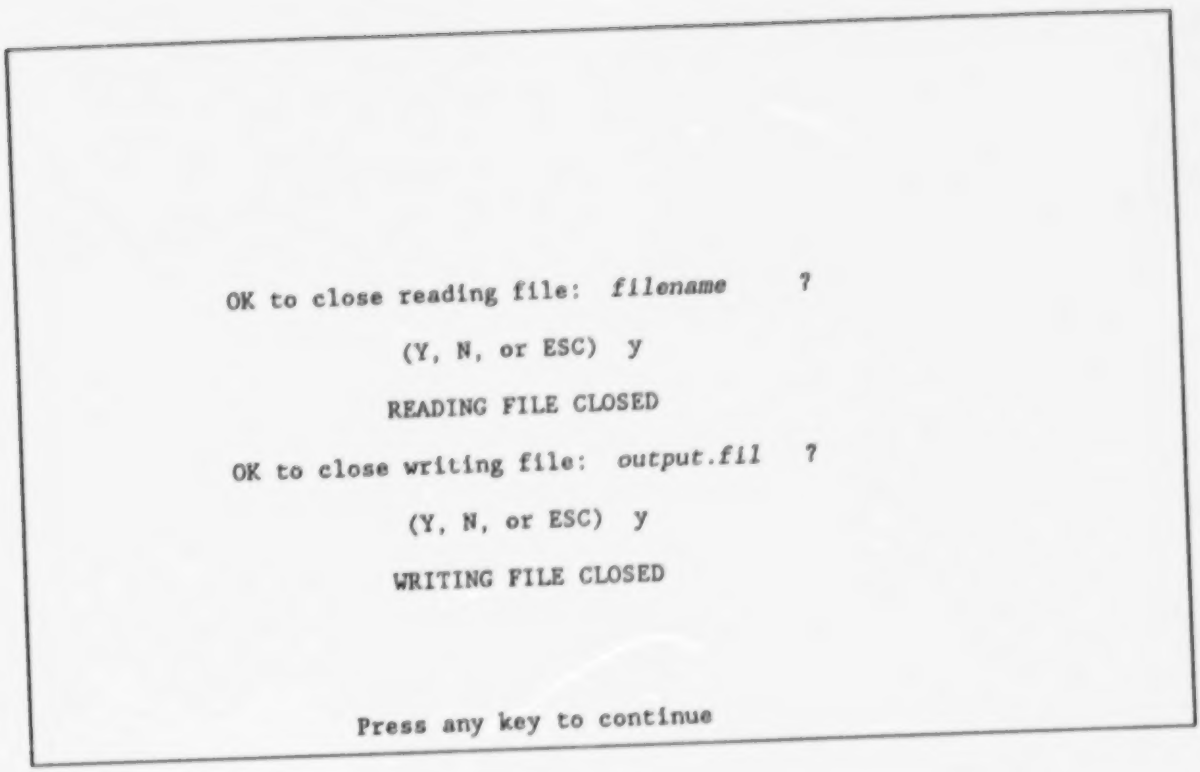

OK to close reading file: filename ?
(Y, N, or ESC) y
READING FILE CLOSED
OK to close writing file: output.fil ?
(Y, N, or ESC) y
WRITING FILE CLOSED
Press any key to continue

Figure 23. Final close files menu.

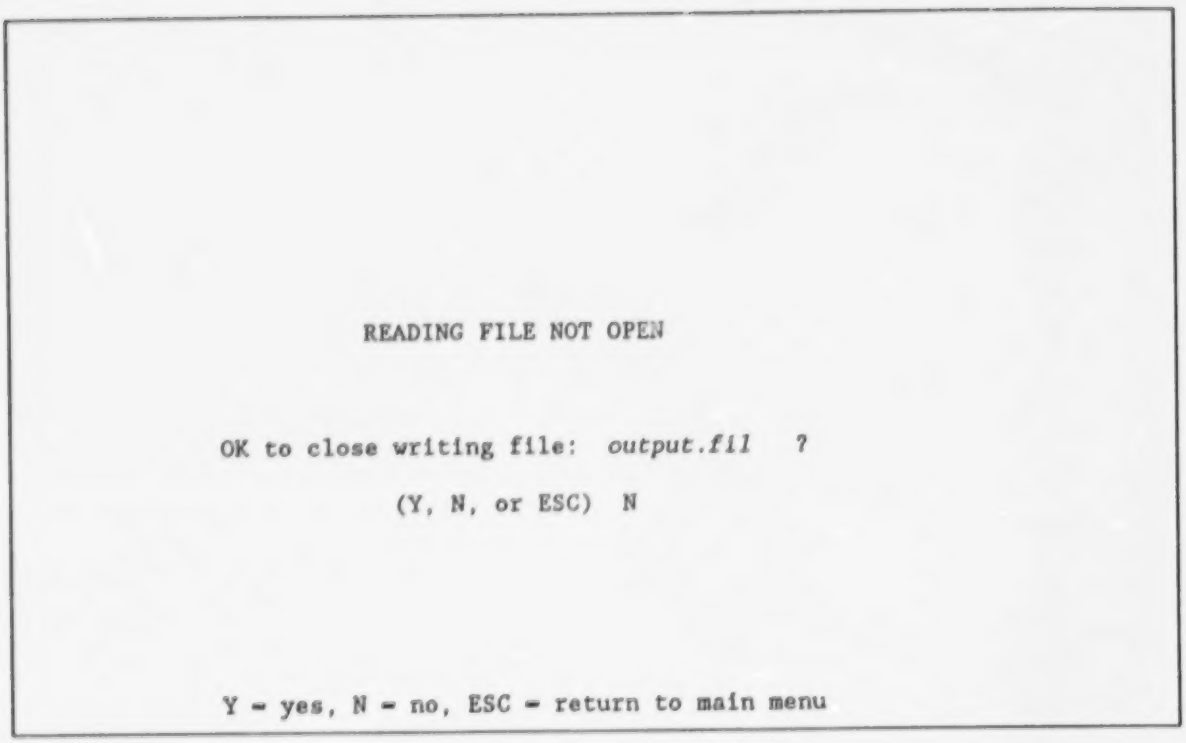


Figure 24. Example of a close files menu when no reading file was open.

SECTION 4

DETAILS CONCERNING SOME OF THE DATA ITEMS

The data entered into this program do not correspond exactly to the data which appear in ESP model data sets. The differences represent little used options, redundant variables, and numbers which can be calculated by the data entry program. This program calculates the numbers where necessary, sets some variables to their most common values, and ignores others. The details are listed below by ESP model variable name and are discussed briefly.

NDATA - This variable allowed the use of shortened data sets to save time and reduce errors when the data were read from punch cards. This feature is no longer necessary when the data are written by the computer. This program reads but does not write shortened data sets.

MODL - This variable allows the model to read metric data or to generate its own data. This program does not use this variable. Metric data are not explicitly treated in this program.

NCOMPS - These are seldom used variables which allow custom tailoring
NWAVES of the opacity calculation. The data for these variables is
NLAMDA usually not available. These variables are not supported in this program.

NEST - These variables determine whether the collecting electric
NCALC field and the charging calculations will be performed rigorously or estimated. This program sets both to either rigorous or estimated. When a data set is read by this program, if either of these variables call for rigorous calculations, both will set to rigorous.

NVI - This variable activates a procedure for deriving unknown electrical operating conditions. It is not used in this program. Data written by this program require the specification of voltages and currents.

NX - These variables determine the interelectrode E-field
NY calculation grid spacing. This program calculates these variables to provide grid spacings of approximately 0.5 in.

NITER - This variable sets the maximum number of iterations of the entire efficiency calculation which can be performed to reach agreement between the estimated and the calculated efficiencies. This program sets this number to 3.

NEFF - This variable determines the way in which the rapping reentrainment mass will be calculated. This program sets this number to 1 so that the rapping mass will be based on the mass collected in the last ESP field.

NTEMP - This variable is the hot or cold side indicator. Its values are 0 or 1 in the data set and H or C in this program.

NN - The number of integrations in the charge calculation is set to 5 by this program.

PL - This program calculates the overall electrical length of the ESP rather than having it entered separately.

FPATH - This variable represents the number of ionic mean free paths over which the momentum of the ions will persist. This program sets it equal to 1, the recommended value.

EBD - This variable is the electrical breakdown strength of the gas or collected dust layer. It is of use only when one of the unknown electrical condition generators is used. This program assigns it a value to avoid having blanks in the listed data.

SYS - The data set calls for 1/2 the wire-to-wire spacing. This program accepts and displays the entire spacing and divides by 2 when writing it to a data file.

VISS - The gas viscosity is calculated by this program.

LINCS - This variable is the length of a single length increment. This program calculates LINCS from the field length and the number of increments.

Appendix A lists all of the input data items which can be read by the ESP model. The data entry model uses most of the more important variables. This section has discussed some items which either do not appear in the data entry program or are treated differently than in the ESP data sets. The remaining data items discussed in Appendix A are for little used options which are available in the main-frame version of the ESP model. They are not present in the PC version of the model and are not supported by this program.

REFERENCES

1. Faulkner, M. G., and DuBard, J. L. A Mathematical Model of Electrostatic Precipitation (Revision 3). EPA-600/7-84-069a,b,c. (Volume I, Modeling and Programming: NTIS PB84-212-679; Volume II, User's Manual: NTIS PB84-212-687; FORTRAN Source Code Tape: NTIS PB84-232-990). U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. 1984.

2. DuBard, J. L. and Dahlin, R. S. Precipitator Performance Estimation Procedure. EPRI CS-5040. Electric Power Research Institute, Palo Alto, California, 1987.

Appendix A

DESCRIPTION OF INPUT DATA[a]

GENERAL DESCRIPTION

The format of the original computer program which performs the calculations in the model for electrostatic precipitation has been re-structured to make the inputting of data less cumbersome. The number of cards which is necessary to input data has been reduced significantly by allowing different operating conditions to be analyzed from one basic set of input data. Due to the fact that several options are available in using the model, the number of cards and type of information in the input data may vary from one set of data to the next. Thus, it is necessary for the user to be familiar with the logic associated with the input data in order to ensure that the desired operations will be performed.

The input variables may be read into the program entirely in metric units or in mixed British and metric units depending on the value of the variable MODL described below. Non-metric data are internally converted to metric units prior to performing the calculations. The input variables and format specifications are discussed in detail in the following section. Where both British and metric units are given, the British units are to be used when mixed units are selected and the metric when all-metric input is selected. Figure A-1 contains a flow chart which shows the logic involved in entering the data.

CONSTRUCTION OF THE BASIC DATA SET

The following is a sequential listing of the variables in the first group of data which is read in, along with the descriptions of the variables and the format specifications.

(1) NENDPT — is the number of discrete points on the cumulative percent versus particle diameter curve. NENDPT is specified by the user and must have a value of at least 1 but not greater than 21. After the collection efficiency has been calculated for one data set, the program will begin reading data for another efficiency calculation starting with this data group. If NENDPT has a value of 99, the program terminates. Thus this data group will be

---

[a]This appendix was taken from the EPA/SRI ESP model report.[1] References to Volume 1 in this appendix refer to Volume I of the ESP model report.

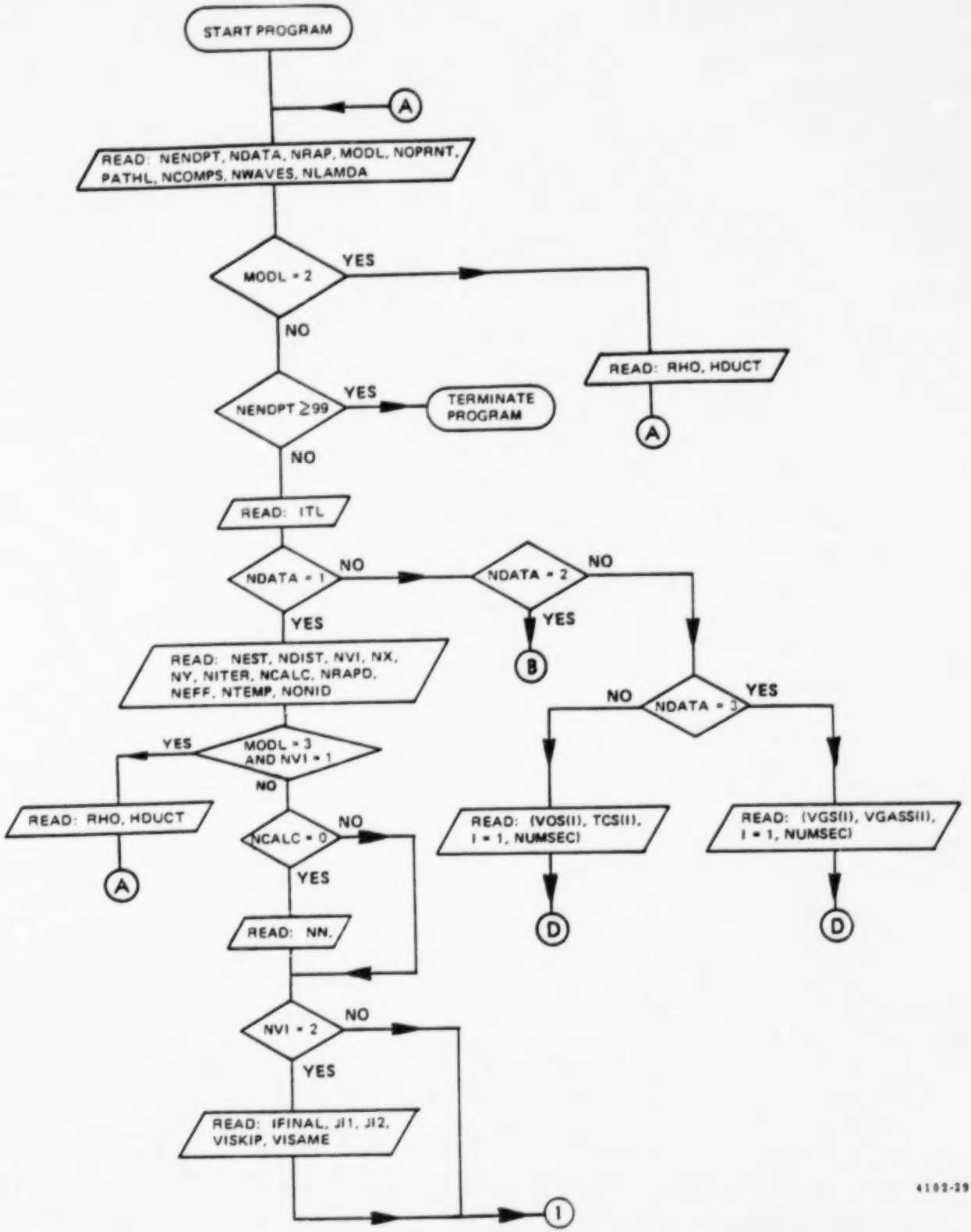


Figure A-1. Flow chart for the input data logic (Sheet 1 of 4).

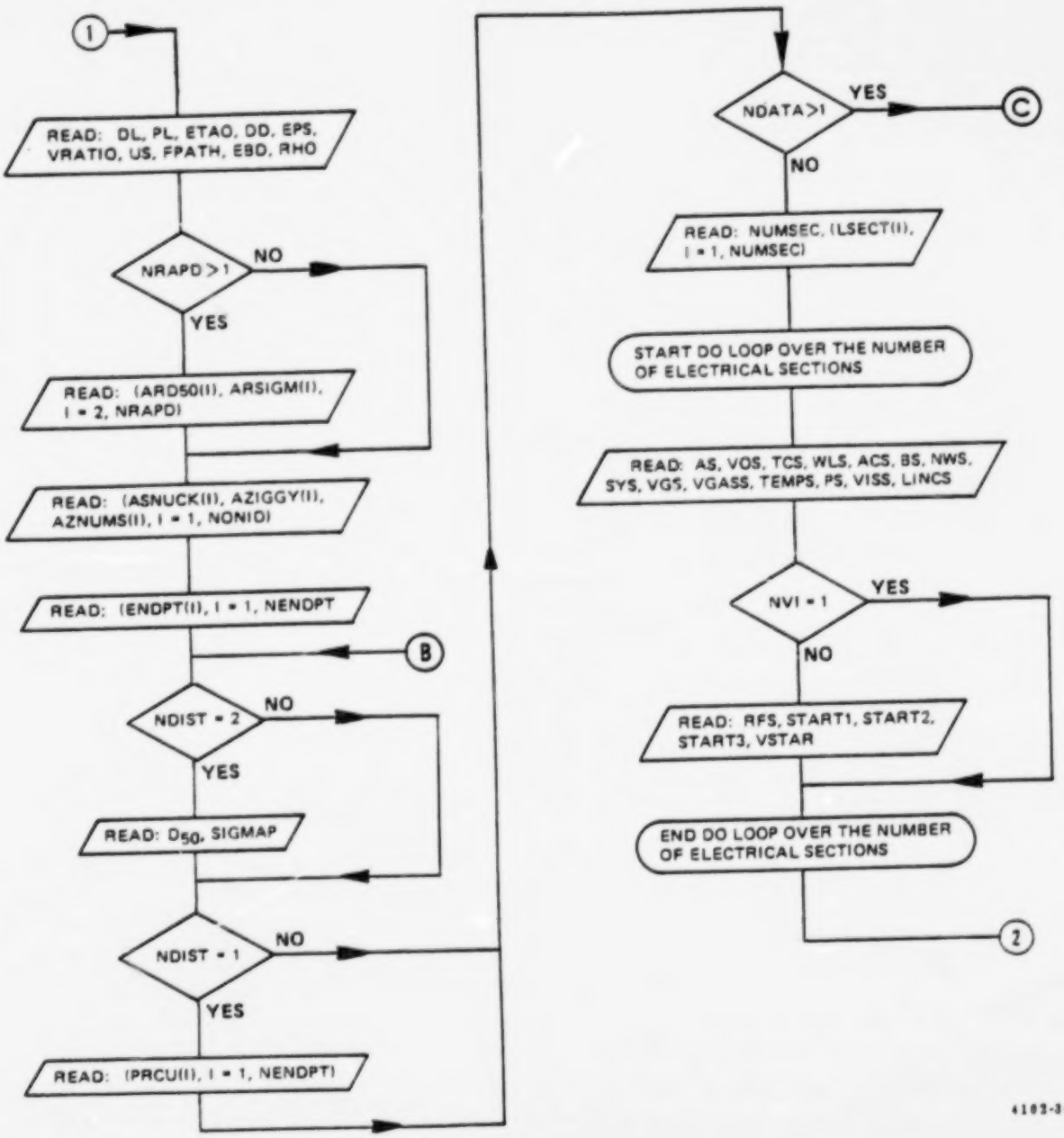


Figure A-1. Flow chart for the input data logic (Sheet 2 of 4).

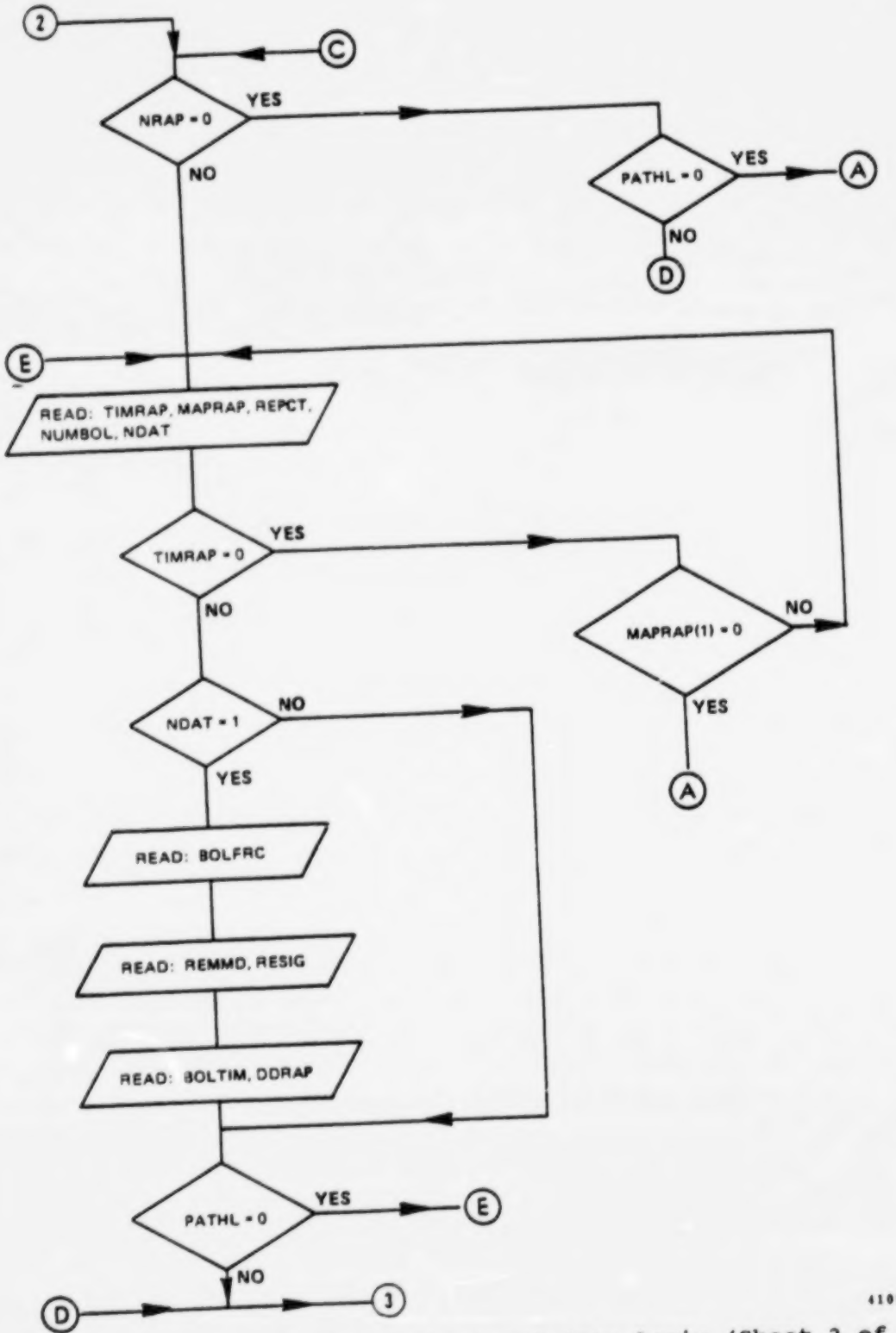


Figure A-1. Flow chart for the input data logic (Sheet 3 of 4).

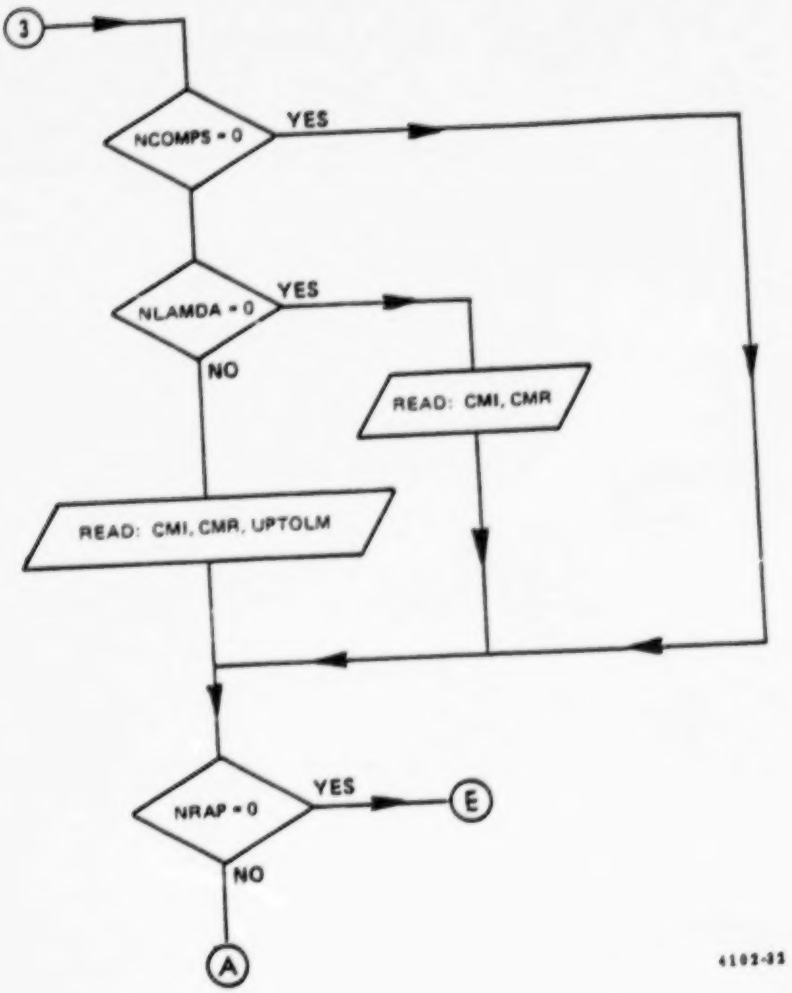


Figure A-1. Flow chart for the input data logic (Sheet 4 of 4).

the first group of each data set and will also be the final card in the input data. If 21<NENDPT<99, the program will terminate abnormally during execution. NENDPT is read in with an I2 format and must be right justified in columns 1-2.

(2) NDATA is an indicator which tells the program to look for a certain type of data set. NDATA can have four possible values which will cause the program to look for the following data set types:

1 - A complete data set must be entered. NDATA must have this value on the first data set.

2 - Only cards 1 and 2 and data concerning size distribution information must be entered. All other data remain as defined in the previous data set. NDATA can have this value only after a basic data set has been run. This value of NDATA allows one to examine the effects of particle size distribution on precipitator performance with all other variables held fixed.

3 - Only cards 1 and 2 and information concerning the gas volume flow and gas velocity must be entered. All other data remain as defined in the previous data set. NDATA can have this value only after a basic data set has been run. This value of NDATA allows one to examine the effects of specific collection area (SCA) on precipitator performance with all other variables held fixed.

4 - Only cards 1 and 2 and information concerning the applied voltage and current must be entered. All other data remain as defined in the previous data set. NDATA can have this value only after a basic data set has been run. This value of NDATA allows one to examine the effects of the electrical conditions on precipitator performance with all other variables held fixed.

NDATA is read in with an I2 format and must be right justified in columns 3-4. If NDATA ≠ 1,2,3, or 4, an error message will be given by the computer at the point in the program where NDATA is used in a "computed go to statement". Depending on the particular computer, the program may or may not terminate at this point. If the program continues to execute, it may terminate abnormally at a later point in the program due to incorrect usage of the

input data. If the program terminates normally, the calculations may or may not be correct, depending on the input data and the action taken by the computer.

(3) NRAP — is an indicator which determines the type of rapping reentrainment correction which will be performed. If NRAP = 0, the correction is performed by the same empirical process used in the previous versions of this model. If NRAP = 1,2, or 3, a different process is used in which additional data are read into the program. From these data, the particle statistics of the reentrained dust are determined. The program then repeats the efficiency calculation for the input dust plus the reentrained dust, which is introduced into the gas flow at that point in the ESP at which it was rapped loose. The additional data required for dynamic rapping will be described later in this section. The values 1,2, or 3 determine the amount of ESP outlet information which is printed with 1 giving extensive details on individual particle statistics and 3 giving summaries only. These effects are described fully in the next section of this report. NRAP is read in with an I2 format and must be right justified in columns 5-6.

(4) MODL — is an indicator which specifies the type of data to be read into the program and may have values from 0 to 3. If MODL = 0, mixed British and metric data are to be used. For MODL = 1, all data must be in metric units. If MODL = 2, an internal data set is used and the only other data required from the user is the resistivity of the input particles and the wire to plate spacing. This data set is described later in this appendix. For MODL = 3, the program terminates after printing the voltage-current curves for the ESP. The options and data sets required when MODL = 3 are described in the section on unknown operating conditions. MODL is read in with an I2 format and must be right justified in columns 7-8.

(5) NOPRNT — is an indicator which may have the values of 0 or 1. If NOPRNT = 0, the printed output includes data on particle charging and, if opacity is calculated, the differential extinction coefficient for each particle size band. If NOPRNT = 1, particle charging data is not printed and only total opacity figures are printed. NOPRNT is read in with an I2 format and must be right justified in columns 9-10.

(6) PATHL — is the path length over which the opacity calculation will be made and is in units of ft or m. PATHL is read in with an F5.2 format in columns 11-15. If PATHL = 0.0, no opacity calculation is performed.

(7) NCOMPS — is the number of indices of refraction for which the opacity is to be calculated. NCOMPS may have values from 0 to 10. If NCOMPS = 0 the two default values of the index of refraction are used. These are 1.50 + 0.0i and 1.50 - 0.10i. If NCOMPS = 1 to 10, the calculation is performed for the values which are read into the program. NCOMPS is read in with an I2 format and must be right justified in columns 19-20.

(8) NWAVES — is the number of wavelengths at which opacity will be calculated and may have values of 0 or 1. If NWAVES = 0, the calculation is performed at 10 different points in the spectrum. If NWAVES = 1, the calculation will be performed at a wavelength of 0.55 μm only. NWAVES is read in with an I2 format and must be right justified in columns 24-25.

(9) NLAMDA — is the number of indices of refraction which must be read in to perform the opacity calculation using an index of refraction that varies with wavelength. NLAMDA may have values from 0 to 10. If NLAMDA = 0, the index of refraction is assumed to be independent of wavelength and no extra data must be read in. If NLAMDA > 0, then NLAMDA indices of refraction and their associated wavelengths are read into the program. If NLAMDA > 0, NCOMPS must have a value of 1 or 2. If NCOMPS = 0, the value of NLAMDA is ignored. If NCOMPS > 2, and NLAMDA > 0, NCOMPS is set equal to 2. NLAMDA is read with an I2 format and must be right justified in columns 29-30.

The overall format for this group is [5I2, F5.2, 3(3X,I2)]. The data contained in this group is on the first card and this card must be the first card in each new data set. However, only the first two parameters, NENDPT and NDATA, are required. The remaining seven parameters are optional. If only the first two parameters are given, the operation of the program is the same as for Revisions I and II except that execution is much faster. Consequently, data sets for the previous version of this model are still usable and will result in the same printed output as before. The use of the optional parameters will result in the inclusion

of the extra processes described in the preceding parameter definitions. The last four parameters (PATHL, NCOMPS, NWAVES, and NLAMDA) define the opacity calculation and are interrelated as shown in Table A-1.

Data group 2 is for specifying information which will identify the data set which is under consideration. All or part of columns 1-80 on data card 2 can be used in identifying the data set. The overall format for this card is (40A2). This data group must be the second card in each new data set.

At this point, the third and successive data groups depend on the choice of the value of NDATA. The basic data set must be read into the program before shortened data sets can be used. For NDATA=1, the program reads in the data groups in the basic data set in the sequence discussed below.

The following is a sequential listing of the variables in data group 3, along with the descriptions of the variables and the format specifications.

(1) NEST — is an indicator which can have the values of 1 and 2. If NEST = 1, the program will perform extensive, detailed calculations in order to determine precipitator performance. If NEST = 2, estimation procedures are used to determine precipitator performance. Both of these options have been discussed in detail. Use of the estimation procedure will result in considerable savings in computer time and can be used to establish trends or to establish ranges over which to apply the more rigorous calculations. NEST is read in with an I2 format and must be right justified in columns 1-2.

(2) NDIST — is an indicator which can have the values of 1 and 2. If NDIST = 1, the user must supply the inlet particle size distribution corresponding to the size bands specified by the variable ENDPT. If NDIST = 2, the program will construct a log-normal particle size distribution for these size bands based on the parameters D50 and SIGMAP. The technique used to construct the log-normal size distribution is described in Volume 1. NDIST is read in with an I2 format and must be right justified in columns 3-4.

(3) NVI — is an indicator which can have the value 1 or 2. If NVI = 1, the user must supply known or measured values of the operating applied voltage and current.

TABLE A-1. OPACITY RELATED INPUT DATA

VALUE OF PARAMETER				CALCULATIONS PERFORMED
PATHL	NCOMPS	NWAVES	NLAMDA	
0.	--	--	--	No opacity calculation performed
>0	0	0	--	Opacity calculated at 10 wavelengths using default values of index of refraction
>0	0	1	--	Opacity calculated at 1 wavelength using default values of index of refraction
>0	1,2	0	0	Opacity calculated at 10 wavelengths using NCOMPS user supplied values of index of refraction
>0	1 to 10	1	0	Opacity calculated at 1 wavelength using NCOMPS user supplied values of index of refraction
>0	1,2	0	1 to 10	Opacity calculated at 10 wavelengths using NLAMDA user supplied values of frequency dependent index of refraction

If NVI = 2, the program will construct a voltage-current curve (or curves) for a specified wire-plate geometry up to a voltage which is specified by the user. Refer to the section on unknown operating conditions (p. A-34) to determine when this option should be used. NVI is read in with an I2 format and must be right justified in columns 5-6.

(4) NX — is the number of grid points in the x-direction (perpendicular to the gas flow) which is used in the numerical techniques that determine the electrical conditions. NX cannot exceed a value of 15. If NVI = 1, sufficient accuracy can normally be obtained with NX > 11. If NVI = 2, NX should be set equal to 15. NX is read in with an I2 format and must be right justified in columns 7-8.

(5) NY — is the number of grid points in the y-direction (parallel to the gas flow) which is used in the numerical techniques that determine the electrical conditions. If NVI = 1, sufficient accuracy can normally be obtained with NY > 9. If NVI = 2, NY should be set equal to 15. NY is read in with an I2 format and must be right justified in columns 9-10.

(6) NITER — is an indicator which serves two different purposes. If NVI = 1, the value of NITER determines the maximum number of iterations the program will make on a loop which converges on overall mass collection efficiency. If the overall mass collection efficiency converges within 0.05% before NITER iterations, the calculation of collection efficiencies is completed at this point. NITER serves the purpose of cutting the calculation off in a reasonable amount of time when convergence requires more iterations and computer time than is warranted. For normal inlet mass loadings and particle size distributions a value of NITER = 2 is sufficient. For high inlet mass loadings or very fine particle size distributions a value of NITER = 3 or 4 may be necessary to provide sufficient accuracy. If NVI = 2, the value of NITER determines the number of iterations which will be performed over each incremental length of the precipitator in order to obtain self-consistent solutions for the electrical conditions. In its present stage of development, the calculation procedure yields the same results for all values of NITER. Thus, in this case, set NITER = 1. The

calculation procedure is discussed in Appendix A of Volume 1. NITER is read in with an I2 format and must be right justified in columns 11-12.

(7) NCALC — is an indicator which can have the values of 0 and 1. If NCALC = 0, particle charge is determined by using equation (12) in Volume 1. Due to the number of times particle charge must be calculated and the use of numerical techniques in order to solve the charging equation, the particle charging calculations for NCALC = 0 take a considerable amount of computer time. If NCALC = 1, particle charge is estimated empirically by using the sum of the charges predicted from classical field and thermal charging theories [see equation (15) in Volume 1]. In this case, particle charge can be determined very rapidly from analytical expressions. Thus, in those cases where a significantly shorter run time is more important than the best accuracy possible, NCALC should be set equal to 1. If NEST = 2, particle charge will be performed as if NCALC = 1 regardless of the value of NCALC. NCALC is read in with an I2 format and must be right justified in columns 13-14.

(8) NRAPD — is an indicator which specifies the number of rapping puff particle size distributions which will be utilized by the program in predicting the effect of rapping reentrainment on overall mass collection efficiency. NRAPD must have a value of at least 1 and can not exceed a value of 10. If NRAPD = 1, the program will determine the rapping puff particle size distribution based on the average of data obtained from several field tests on full-scale precipitators. These tests yield an average rapping puff particle size distribution with a mass median diameter (MMD) of 6.0 μm and a geometric standard deviation (σ_p) of 2.5. The technique which is used to predict rapping losses is discussed in Volume 1. If NRAPD is greater than 1, the user must supply a MMD and σ_p of a log-normal distribution corresponding to each value of NRAPD greater than 1. The program will determine the rapping puff particle size distribution based on the specified combinations on MMD and σ_p. The case for NRAPD = 1 will always be performed. Each rapping puff particle size distribution is used in conjunction with the same basic ideal calculation and its effect is determined with very little expenditure of computer time. NRAPD is read in with an I2 format and must be right justified in columns 15-16.

(9) NEFF — is an indicator which can have the values of 1 and 2. If NEFF = 1, the total mass reentrained at the outlet due to rapping is determined from the mass collected in the last field under adjusted no-rap conditions. If NEFF = 2, the total mass reentrained at the outlet due to rapping is determined from the mass which would be collected in the last field under unadjusted ideal conditions. NEFF should normally be taken to be 1 since this case is physically meaningful. A value of NEFF = 2 will result in rapping losses which are significantly greater than for NEFF = 1. Thus, a value of NEFF = 2 should only be used when a precipitator design which is conservative with respect to rapping losses is desired. NEFF is read in with an I2 format and must be right justified in columns 17-18.

(10) NTEMP — is an indicator which can have the values of 1 and 2. The mass reentrained due to rapping will differ for cold-side and hot-side precipitators. If NTEMP = 1, the mass reentrained due to rapping is estimated based on an equation for cold-side precipitators. If NTEMP = 2, the mass reentrained due to rapping is estimated based on equation for hot-side precipitators. NTEMP is read in with an I2 format and must be right justified in columns 19-20.

(11) NONID — is an indicator which specifies the number of combinations of normalized gas velocity standard deviation (σ_g) and gas bypassage fraction and/or particle reentrainment fraction without rapping (S) which are to be used to simulate the possible nonideal conditions. The procedures used to account for these nonideal effects are described in Volume 1. NONID must have a value of at least 1 and can not exceed a value of 15. Each set of nonideal conditions is used in conjunction with the same basic ideal calculation and its effect is determined with very little expenditure of computer time. NONID is read in with an I2 format and must be right justified in columns 21-22.

The overall format for this data group is (11I2) and all the data are contained on the third data card.

The next data group which is read in depends on the values of NCALC and NVI. If NCALC = 0, the rigorous charging theory is used. In this case, the following is a sequential listing of the

variables in the next data group which is read in, along with the descriptions of the variables and the format specifications.

(1) NN — is the number of increments in the Runge-Kutta integration of equation (12) in Volume 1. A value of NN = 5 will provide sufficient accuracy for normal use. Greater values found in data sets created for previous versions of the model may be used but will result in an increase in computer time for no appreciable increase in accuracy. NN is read in with an I2 format and must be right justified in columns 1-2.

(2) NUMINC — was previously the number of increments in the Simpson's Rule integration over θ in equation (12) in Volume 1. Since this integration is now done by the Gaussian Quadrature method, this variable is no longer used. Data sets containing this variable may still be used, however, as the space allowed to NUMINC, columns 3-4, is not used for any other purpose.

The overall format for this data group is (I2) and all the data are contained on a single card. If NCALC = 1, the above data group is not read into the program.

If NVI = 2, the model must calculate a voltage-current curve. In this case, the following is a sequential listing of the variables in the next data group which is read in, along with the descriptions of the variables and the format specifications.

(1) IFINAL — is an indicator which causes the calculation of successive points on the voltage-current curve to cease after IFINAL points. This indicator allows the user to have the voltage-current calculation terminated at a point before the specified operating voltage is reached whenever it is taking an excessive number of points to reach the specified operating voltage. IFINAL is read in with an I2 format and must be right justified in columns 1-2.

(2) JI1 — is an indicator which allows the initial increment size on current density in the calculation of the voltage-current curve to be changed after JI1-1 points are determined on the curve. Since the voltage-current calculation finds the applied voltage corresponding to a specified value of current density, this indicator allows the user to cover a large range of current densities without using an excessive number of points. JI1 is read in with an I2 format and must be right justified in columns 3-4.

(3) JI2 — is an indicator which allows the second increment size on current density in the calculation of the voltage-current curve to be changed after JI2-1 points are determined on the curve. JI2 serves the same function as JI1 and JI2 must have a value greater than JI1 for proper usage. JI2 is read in with an I2 format and must be right justified in columns 5-6.

(4) VISKIP — is an indicator which may have the values of 0 and 1. If VISKIP = 0, a voltage-current curve will be calculated up to a specified operating voltage for each successive length increment of the precipitator. If VISKIP = 1, only the operating current density which corresponds to a specified operating voltage will be calculated based on an estimation procedure discussed in Volume 1. In most cases, the user will want to set VISKIP = 1 since this will result in a prediction of the operating current density in each increment of length of the precipitator without using the large amounts of computer time required by the calculation of a voltage-current curve. Only extremely detailed analysis would warrant setting VISKIP = 0. VISKIP is read in with an I2 format and must be right justified in columns 7-8.

(5) VISAME — is an indicator which may have the values of 1 and 2. The proper use of VISAME can result in significant savings in computer time whenever the applied voltage is the same in each electrical section. If the applied voltage is the same in each electrical section, set VISAME = 1 and only one "clean" voltage-current curve will be calculated. If VISAME = 1, as many data sets as desired can be read into the program and all calculations will be based on the one "clean" voltage-current calculation. The use of VISAME = 1 is especially beneficial in studying hypothetical cases due to the large savings in computer time. If the applied voltage differs from one electrical section to the next, the user must set VISAME = 2. Whenever the operating voltage and current are unknown and the user must specify the use of the voltage-current calculations (NVI = 2), the quickest run time will occur when VISKIP = 1 and VISAME = 1. The longest run time will occur when VISKIP = 0 and VISAME = 2. VISAME is read in with an I2 format and must be right justified in columns 9-10.

The overall format for this data group is (5I2) and all data are contained on single card. If NVI = 1, the above data group is not read into the program.

The following is a sequential listing of the next data group which is read in, along with the descriptions of the variables and the format specifications.

(1) DL — is the inlet particulate mass loading in units of grains/ft^3 or kg/m^3. DL is read in with a F8.0 format and must be left justified in columns 1-8.

(2) PL — is the total electrical length of the precipitator in units of ft or m. PL is read in with a F8.0 format and must be left justified in columns 9-16.

(3) ETAO — is the overall mass collection efficiency in units of percent and it has two different interpretations depending upon the value of NVI. If NVI = 1, ETAO represents the measured or estimated overall mass collection efficiency and is used as a test for convergence in an iteration loop on overall mass collection efficiency. If NVI = 2, ETAO simply represents the desired design efficiency and is not used in the calculations. ETAO is read in with a F8.0 format and must be left justified in columns 17-24.

(4) DD — is the density of the particles in units of kg/m^3. DD is read in with a F8.0 format and must be left justified in columns 25-32.

(5) EPS — is the dielectric constant of the particles for use in the particle charging calculations and is dimensionless. Values of EPS must be equal to or greater than 1. In most industrial applications, the flue gas is sufficiently humidified that the particle surface becomes conductive and a value of EPS = 100 can be used to simulate a conductor. EPS is read in with a F8.0 format and must be left justified in columns 33-40.

(6) VRATIO — is the ratio of the peak voltage to the average voltage and is dimensionless. In the calculation of particle charge, it is assumed that the particles will charge to an extent determined by the peak voltage rather than the average voltage. For industrial applications, VRATIO has a value around 1.2. VRATIO is read in with a F8.0 format and must be left justified in columns 41-48.

(7) US — is the ionic mobility at standard temperature (273 K) and standard pressure (1 atm) and is in units of $m^2/(V\text{-}sec)$. This mobility is referred to as the "reduced mobility". Values to use for reduced ionic mobilities for flue gas compositions are not well-established at the present time. The reduced ionic mobility for air is in the range 1.2-2.1 x $10^{-4} m^2/(V\text{-}sec)$. Reduced ionic mobilities for flue gas compositions have been reported that are considerably larger than those reported for air. These values cover the range of 2.2-5.4 x $10^{-4} m^2/(V\text{-}sec)$. Some reported values of reduced ionic mobility for various gas compositions are given in Table A-2. Since the ionic mobility has a strong influence on the electrical conditions through the current and electric field distributions, this is an important parameter in determining precipitator performance. A value of 2.7 x $10^{-4} m^2/(V\text{-}sec)$ should provide a representative value to use for flue gases emanating from coal-fired boiler applications. US is read in with a F8.0 format and must be left justified in columns 49-56.

(8) FPATH — is a parameter which is used in the field charging equation and is dimensionless. FPATH represents the number of ionic mean free paths over which the momentum of the ions will persist and allow the ions to reach the surface of the particle even though the saturation charge has been reached. The effect of this parameter is to increase the saturation charge. FPATH normally should have a value in the range 0-2. It is recommended that FPATH be assigned a value of 1. FPATH is read in with a F8.0 format and must be left justified in columns 57-64.

(9) EBD — is the electrical breakdown strength of the gas or the particulate layer in the region near the plate and is in units of V/m. The value of this parameter is a strong function of the resistivity of the collected particulate layer and the condition of the collection plates. At present, mathematical techniques which are based on physical principles do not exist for predicting the value of EBD under differing conditions. Thus, experimental data and prior experience must be used to choose appropriate values of EBD. In practical applications, EBD falls in the range of 2-15 kV/cm. A value of 2 kV/cm should provide a conservative estimate of EBD whereas a value of 15 kV/cm would

TABLE A-2

REDUCED EFFECTIVE NEGATIVE ION MOBILITIES FOR VARIOUS GAS COMPOSITIONS

Gas Composition (Volume Percent)					Reduced Effective Ion Mobility (cm^2/V-sec)
N_2	CO_2	O_2	SO_2	H_2O	
				100.0	0.67 ± 0.17[a]
		100.0			2.46 ± 0.06[b]
	100.0				1.08 ± 0.03[b]
			100.0		0.35[c]
	(Laboratory Air)				1.03[d]
	(Laboratory Air)				1.26 - 1.96[e]
79.4	14.7	4.6	0.2	0.6	5.39[f]
73.5	13.6	4.2	0.2	8.4	2.93[f]
65.9	12.2	3.8	0.2	17.8	2.23[f]
71.0	11.2	3.7	0.0	14.0	2.35[f]
75.7	11.6	3.2	0.0	9.4	3.02[f]
75.1	11.5	3.2	0.1	9.9	2.74[f]
78.5	10.9	3.6	0.0	7.0	3.36[f]
78.3	19.8	3.6	0.1	7.0	2.67[f]
77.9	10.8	3.6	0.3	7.0	2.70[f]
77.6	10.7	3.7	0.7	7.0	2.43[f]

---

a. J. J. Lowke and J. A. Rees, Australian J. Phys. 16, 447 (1963).

b. E. W. McDaniel and H. R. Crane, Rev. Sci. Instru. 28, 684 (1959).

c. E. W. McDaniel and M. R. C. McDowell, Phys. Rev. 114, 1028 (1959).

d. B.Y.H. Liu, K. T. Whitby, and H.H.S. Yu, J. Appl. Phys. 38, 1592 (1967).

e. J. Bricard, M. Cabane, G. Modelaine, and D. Vigla, Aerosols and Atmospheric Chemistry. Edited by G. M. Hidy, New York, New York, 27 (1972).

f. H. W. Spencer, III, "Experimental Determination of the Effective Ion Mobility of Simulated Flue Gas." In Proceedings of 1975 IEEE-IAS Conference, September 28, 1975, Atlanta, Georgia.

in most cases provide the most optimistic value. The value of EBD is used whenever NVI = 2 and a voltage-current curve is generated. If the field at the plate exceeds the value of EBD at any point on the curve, a message to this effect is printed out with the voltage-current calculation terminating at the corresponding applied voltage and current density. These values of voltage and current are then used in the projection of precipitator performance. EBD is read in with a F8.0 format and must be right justified in columns 65-72.

(10) RHO — is the resistivity of the collected particulate layer and is in units of ohm-cm. The resistivity to be used must be determined experimentally by either in situ or laboratory methods. RHO is used in the model only if the operating conditions are unknown. For this use refer to the section on unknown operating conditions (p. A-34). RHO is read in with an 8.2 format and must be right justified in columns 73-80.

> When the operating voltages and current are specified, the value of RHO has no effect on the operating conditions. To estimate the effects of a change in RHO, the procedures listed under unknown operating conditions must be used.

The above data group has an overall format of (9F8.0, E8.2) and is contained on a single data card. This data set must be read in with each basic data set, i.e. when NDATA = 1.

The next data group which is read in depends on the value of NRAPD. If NRAPD is greater than 1, the following is a sequential listing of the variables in the next data group, along with the descriptions of the variables and the format specifications.

(1) ARD50(I) — is an array containing the mass median diameters in μm for log-normal particle size distributions of the different rapping puff distributions which will be utilized in the model. The values of this variable are read in with a F4.0 format and must be left justified in columns 1-4, 9-12, 17-20, 25-28, 33-36, 41-44, 49-52, 57-60, 65-68, and 73-76.

(2) ARSIGM(I) — is an array containing the geometric standard deviations for log-normal particle size distributions of the different rapping puff distributions which will be utilized in the model.

Values of ARD50(I) and ARSIGM(I) with the same index are used together to construct a log-normal particle size distribution. The values of this variable are read in with a F4.0 format and must be left justified in columns 5-8, 13-16, 21-14, 29-32, 37-40, 45-48, 53-56, 61-64, 69-72, and 77-80. ARSIGM(I) can not have a value less than 1.

The above variables must be read in for I=2 up to I=NRAPD where NRAPD can not exceed a value of 10. The overall format for this data group is [10(2F4.0)] and is contained on a single data card. If NRAPD=1, this data group is not read in. In this case, only one rapping puff particle size distribution will be considered where ARD50(1) = 6.0 in μm and ARSIGM(1) = 2.5. This case is built into the program and relates to experimental data discussed in Volume 1.

The following is a sequential listing of the variables in the next data group which is read in, along with the descriptions of the variables and the format specifications.

(1) ASNUCK(I) is an array containing different fractions of gas flow which bypass the electrified region in each baffled stage of the precipitator and/or different fractions of the mass collected in each stage of the precipitator which are reentrained due to factors other than rapping. The values of this variable are read in with a F4.0 format and must be left justified in columns 1-4, 13-16, 25-28, 37-40, 49-52, and 61-64 of the first two data cards in the group and in columns 1-4, 13-16, and 25-28 of the third data card in the group. ASNUCK(I) must lie in the range 0.0 to 1.0.

(2) AZIGGY(I) is an array containing different normalized standard deviations for the inlet velocity distribution of the gas flow. The values of this variable are read in with a F4.0 format and must be left justified in columns 5-8, 17-20, 29-32, 41-44, 53-56, and 65-68 of the first two data cards in the group and in columns 5-8, 17-20, and 29-32 of the third data card in the group. AZIGGY(I) must be equal to or greater than 0.0.

(3) AZNUMS(I) is an array containing the number of baffled stages in the precipitator. The values of this variable are read in with a F4.0 format and must be left justified in columns 9-12, 21-24, 33-36, 45-48, 57-60, and 69-72 of the first two data cards in the group and in columns 9-12, 21-24, and 33-36 of the third data card in the group. The values of AZNUMS(I) must be whole numbers.

The values of ASNUCK(I), AZIGGY(I), and AZNUMS(I) with the same index are used together to simulate one set of nonideal parameters and to produce one set of no-rap efficiencies. The values of I are determined by NONID which must have a value of at least 1 and can not exceed a value of 15. Thus, at least one set of these parameters must be read in. It is recommended that the user take the first set of these variables to be ASNUCK(1) = 0.00, AZIGGY(1) = 0.00, and AZNUMS(1) = actual number of stages so that efficiencies under ideal conditions will be obtained. In practical situations, a well-operating precipitator will have values of ASNUCK and AZIGGY of approximately 0.1 and 0.25, respectively.

The overall format for this data group is [6(3F4.0)] and the data group is contained on 3 or less cards. For NONID ≤ 6, 6<NONID ≤ 12, and 12<NONID ≤ 15, the number of data cards necessary are 1, 2, and 3, respectively. This data group must be read in with each basic data set.

The next data group which is read in consists of a single array. The description of this array and its format specification are given below.

(1) ENDPT(I) is an array containing values of particle diameters corresponding to points on a curve of inlet mass cumulative percent versus particle diameter. The number of diameters read in must equal the value of NENDPT which can not exceed a value of 21. The diameters must be entered in order from smallest to largest in units of μm. The smallest diameter can not be less than 0.01 μm and the largest diameter can not exceed 1,000 μm. These diameters are used to construct particle size intervals and a particle size histogram. The midpoints between successive particle diameters constitute NENDPT-1 average particle diameters which are used in the program to characterize the different particle size bands. In constructing the particle diameters to be used in the calculations, it is recommended that greater resolution be built into the fine particle size range of 0.1-3.0 μm since the lower efficiencies are obtained in this size range. The values of ENDPT(I) are read in with a F8.0 format and must be left justified.

The overall format for this data group is (10F8.0) and the data group is contained on 3 or less data cards. For NENDPT ≤ 10, 10<NENDPT ≤ 20, and NENDPT = 21, the number of data cards necessary are 1, 2, and 3, respectively. This data group must be read in with each basic data set.

The next data group which is read in depends on the value of NDIST. If NDIST = 2, the following is a sequential listing of the variables in the next data group, along with the descriptions of the variables and the format specifications.

(1) D50 — is the mass median diameter of a log-normal inlet particle size distribution and is in units of μm. The value of D50 must lie between 0.01 and 1,000 μm. The value of D50 is read in with a F8.0 format and must be left justified in columns 1-8.

(2) SIGMAP — is the geometric standard deviation of a log-normal inlet particle size distribution and is dimensionless. The value of SIGMAP must be equal to or greater than 1. The value of SIGMAP is read in with a F8.0 format and must be left justified in columns 9-16.

The program uses the values of D50 and SIGMAP to construct a log-normal particle size distribution over the range and size bands determined by the values of ENDPT(I). Any mass which is not in the size range determined by ENDPT(I) will be put into the size band with the largest midpoint. This must be done to ensure that the sum over all size bands of the percentage of total mass in each size band will equal 100%.

The above data group has an overall format of (2F8.0) and is contained on a single data card. This data set is not read in if NDIST = 1.

If NDIST = 1, the next data group which is read in consists of a single array. The description of this array and its format specification are given below.

(1) PRCU(I) — is an array containing values of cumulative percents corresponding to points on a curve of inlet mass cumulative percent versus particle diameter. The number of cumulative percents read in must equal the value of NENDPT which can not exceed 21. The cumulative percents must match the particle diameters specified in the array ENDPT(I). The cumulative percents are entered in units of %. The first value of PRCU(I) must be 0% and the last value must be 100%. The program determines the percentage by mass in each particle size band from the values contained in ENDPT(I) and PRCU(I). The user must supply values of PRCU(I) based on measured or known particle size information for the particular application under consideration. The values of PRCU(I) are read in with a F8.0 format and must be left justified.

The overall format for this data group is (10F8.0) and the data group is contained on 3 or less data cards. For NENDPT ≤ 10, 10<NENDPT ≤ 20, and NENDPT = 21, the number of data cards necessary are 1, 2, and 3, respectively. This data group is not read in if NDIST = 2.

The following is a sequential listing of the variables in the next data group which is read in, along with the descriptions of the variables and the format specifications.

(1) NUMSEC is the number of electrical sections in the direction of gas flow. The maximum number of electrical sections which can be accounted for in the program listed in Volume 1 is 10. The value of this variable is read in with an I2 format and must be right justified in columns 1-2.

(2) LSECT(I) is an array containing values of the number of incremental lengths to be taken in each electrical section in the direction of gas flow. These values are determined by the user with increasing values of I corresponding to electrical sections moving from the inlet to the outlet of the precipitator. The total number of incremental lengths in all sections must not exceed 99. It is not necessary to have the same number in each section. The values of this variable are read in with an I2 format and must be right justified.

The overall format for this data group is (I2, 10I2) and the data group is contained on a single data card. This data group must be read in with each basic data set.

The following is a sequential listing of the variables in the next data group which is read in, along with the descriptions of the variables and the format specifications.

(1) AS(NSECT) is the total collection plate area for a given electrical section and is in units of ft^2 or m^2. The values of this variable are read in with an E11.4 format and must be right justified in columns 1-11.

(2) VOS(NSECT) is the applied voltage in a given electrical section and is in units of volts. If NVI = 1, the value of VOS(NSECT) corresponds to a measured or known value. If NVI = 2, VOS(NSECT) corresponds to an applied voltage up to which a voltage-current curve will be calculated. Then, this applied voltage along with the corresponding current will

be used in the calculation of precipitator performance. The values of this variable are read in with an E11.4 format and must be right justified in columns 12-22.

(3) TCS(NSECT) is the total current in a given electrical section and is in units of amperes. If NVI = 1, the value of TCS(NSECT) corresponds to a measured or known value. If NVI = 2, TCS(NSECT) has no meaning in terms of input data since it will be calculated in the program. In this case, the appropriate columns on the data card can be left blank or any arbitrary number can be entered. The values of this variable are read in with an E11.4 format and must be right justified in columns 23-33.

(4) WLS(NSECT) is the total effective wire length in a given electrical section and is in units of ft or m. The values of this variable are read in with an E11.4 format and must be right justified in columns 34-44.

(5) ACS(NSECT) is the corona wire radius in a given electrical section and is in units of in. or mm. The values of this variable are read in with an E11.4 format and must be right justified in columns 45-55.

(6) BS(NSECT) is the wire-to-plate spacing in a given electrical section and is in units of in. or m. The values of this variable are read in with an E11.4 format and must be right justified in columns 56-66.

(7) NWS(NSECT) is the number of discharge electrodes per given electrical section per gas passage and is dimensionless. The values of this variable normally should not exceed 20. If the values do exceed 20, use 20 in the program. These values are used to determine the number of terms in a series summation which determines the electrostatic electric field distribution and 20 terms are more than sufficient to reach convergence. The values of this variable are read in with an E11.4 format and must be right justified in columns 67-77.

(8) SYS(NSECT) is one-half of the wire-to-wire spacing in a given electrical section and is in units of in. or m. The values of this variable are read in with an E11.4 format and must be right justified in columns 1-11.

(9) VGS(NSECT) is the total gas volume flow rate in a given electrical section and is in units of actual ft^3/min or m^3/sec. The values of this variable are read in with an E11.4 format and must be right justified in columns 12-22.

(10) VGASS(NSECT) is the gas velocity in a given electrical section and is in units of ft/sec or m/sec. The values of this variable are read in with an E11.4 format and must be right justified in columns 23-33. The gas velocity must be consistent with the gas volume flow rate and the precipitator geometry in each electrical section. These are related by

VGASS(I) = [LINCS(I)*LSECT(I)*VGS(I)]/[AS(I)*BS(I)*Constant],

where the constant = 1 for metric units and 5 for British units.

(11) TEMPS(NSECT) is the gas temperature in a given electrical section and is in units of °F or °C. The values of this variable are read in with an E11.4 format and must be right justified in columns 34-44.

(12) PS(NECT) is the gas pressure in a given electrical section and is in units of atmospheres. The values of this variable are read in with an E11.4 format and must be right justified in columns 45-55.

(13) VISS(NSECT) is the gas viscosity in a given electrical section and is in units of kg/(m-sec). Table A-3 gives values of viscosity for different temperatures and water contents for a gas composition whose components are those of air. This table provides values of viscosity which cover most cases found in practice although some extrapolation is necessary for those cases involving hot precipitators where temperatures are greater than 300°C. The values of this variable are read in with an E11.4 format and must be right justified in columns 56-66.

(14) LINCS(NSECT) is the incremental length size which will be taken in a given electrical section and is in units of ft or m. If NVI = 1, LINCS(NSECT) should be given a value of approximately 1 ft although larger values can be used with some loss in accuracy in order to save computer run time. If NVI = 2, LINCS(NSECT) must be given a value equal as near as possible to the wire-to-wire spacing in order for the numerical procedure to be valid. In any case, the product of LSECT(NSECT) and

TABLE A-3. VALUES OF VISCOSITY FOR AIR AT VARIOUS TEMPERATURES AND WATER CONTENTS [a]

	Percent H_2O										
°C	0	1	2	3	4	5	6	7	8	9	10
10	1.767	1.758	1.748	1.739	1.730	1.721	1.712	1.702	1.693	1.684	1.675
20	1.810	1.801	1.792	1.783	1.774	1.765	1.755	1.746	1.737	1.728	1.719
30	1.854	1.844	1.835	1.826	1.817	1.808	1.799	1.790	1.780	1.771	1.762
40	1.900	1.887	1.878	1.869	1.860	1.850	1.841	1.832	1.823	1.814	1.805
50	1.938	1.929	1.920	1.911	1.902	1.892	1.883	1.874	1.865	1.856	1.847
60	1.979	1.970	1.961	1.952	1.943	1.934	1.925	1.916	1.907	1.898	1.888
70	2.020	2.011	2.002	1.993	1.984	1.975	1.966	1.957	1.948	1.939	1.930
80	2.059	2.050	2.042	2.033	2.024	2.015	2.006	1.997	1.988	1.979	1.970
90	2.099	2.090	2.081	2.072	2.063	2.054	2.046	2.037	2.028	2.019	2.010
100	2.137	2.129	2.120	2.111	2.102	2.093	2.085	2.076	2.067	2.058	2.049
110	2.175	2.167	2.158	2.149	2.140	2.132	2.123	2.114	2.105	2.097	2.088
120	2.213	2.204	2.195	2.189	2.178	2.169	2.161	2.152	2.143	2.135	2.126
130	2.250	2.241	2.232	2.224	2.215	2.207	2.198	2.189	2.181	2.172	2.164
140	2.286	2.277	2.269	2.260	2.252	2.243	2.235	2.226	2.218	2.209	2.201
150	2.321	2.313	2.304	2.296	2.288	2.279	2.271	2.262	2.254	2.245	2.237
160	2.356	2.348	2.339	2.331	2.323	2.315	2.306	2.298	2.289	2.281	2.273
170	2.390	2.382	2.374	2.366	2.358	2.349	2.341	2.333	2.325	2.316	2.308
180	2.424	2.416	2.408	2.400	2.392	2.383	2.375	2.367	2.359	2.351	2.343
190	2.457	2.449	2.441	2.433	2.425	2.417	2.409	2.401	2.393	2.385	2.377
200	2.489	2.482	2.474	2.466	2.458	2.450	2.442	2.434	2.426	2.418	2.410
210	2.521	2.513	2.506	2.498	2.490	2.482	2.475	2.467	2.459	2.451	2.443
220	2.552	2.545	2.537	2.530	2.522	2.514	2.507	2.499	2.491	2.483	2.476
230	2.583	2.575	2.568	2.560	2.553	2.545	2.538	2.530	2.523	2.515	2.507
240	2.613	2.606	2.598	2.591	2.583	2.576	2.569	2.561	2.554	2.546	2.539
250	2.642	2.635	2.628	2.621	2.613	2.606	2.599	2.592	2.584	2.577	2.570
260	2.671	2.664	2.657	2.650	2.643	2.636	2.628	2.621	2.614	2.607	2.600
270	2.699	2.692	2.685	2.678	2.671	2.664	2.657	2.650	2.643	2.636	2.629
280	2.727	2.720	2.713	2.706	2.700	2.693	2.686	2.679	2.672	2.665	2.658
290	2.754	2.747	2.740	2.734	2.727	2.720	2.714	2.707	2.700	2.694	2.687
300	2.780	2.773	2.767	2.761	2.754	2.748	2.741	2.734	2.728	2.721	2.715

X 10^{-5} kg/(m-sec)

[a] Calculations according to:
C.R. Wilke. A Viscosity Equation for Gas Mixtures. J. Chem. Phy., 18(4):517-519 (April, 1950).

LINCS(NSECT) must equal the total length of the given electrical section. The values of this variable are read in with an E11.4 format and must be right justified in columns 67-77.

The overall format for this data group is [7(E11.4)] and the data group is contained on two data cards. This data group must be read in with each basic data set.

The next data group which is read in depends on the value of NVI. If NVI = 2, the following is a sequential listing of the variables in the next data group which is read in, along with the descriptions of the variables and the format specifications.

(1) RFS(NSECT) is the roughness factor for the wires in a given electrical section and is dimensionless. In precipitation practice, if the wires are scratched or dirty but not completely coated with air, then the values of RFS(NSECT) lie in the range 0.5-1.0. A value of 1.0 corresponds to wires which are in perfect condition. The effect of decreasing the roughness factor is one of increasing the current that can be achieved at a given voltage level. If the wires are completely covered with dirt, then the effect may be one of increased wire diameter with a roughness superimposed. This situation would lead to compensating effects. The values of this variable are read in with an E11.4 format and must be right justified in columns 1-11.

(2) START1(NSECT) is the chosen initial current density at which the calculation of a voltage-current curve starts in a given electrical section and is in units of A/m^2. In generating the voltage-current curve, the current density increments in steps of START1 (NSECT) until a change is specified. The values of this variable are read in with an E11.4 format and must be right justified in columns 12-22.

(3) START2(NSECT) is a chosen increment in current density which is used in place of START1(NSECT) when the JI1-th point on the voltage-current curve is reached and is in units of A/m^2. The values of this variable are read in with an E11.4 format and must be right justified in columns 23-33.

(4) START3(NSECT) is a chosen increment in current density which is used in place of START2(NSECT) when the JI2-th point on the voltage-current curve is reached and is in units of A/m^2. The values of this variable

are read in with an E11.4 format and must be right justified in columns 34-44.

(5) VSTAR(NSECT) is an estimate of the applied voltage corresponding to the first point on the voltage-current curve as defined by START1(NSECT) and is in units of volts. If VSTAR(NSECT) is close to the actual applied voltage, the calculation will be performed faster. However, whatever the choice of VSTAR(NSECT), it will not affect the accuracy of the calculation. The values of this variable are read in with an E11.4 format and must be right justified in columns 45-55.

The overall format for this data group is [7(E11.4)] and the data group is contained on a single data card. If NVI = 1, this data group is not read in.

The data input starting with AS(NSECT) above must be repeated for each electrical section of the precipitator, proceeding from the inlet to the outlet of the precipitator. Thus, the data group containing AS(NSECT) and possibly the data group containing RFS(NSECT) must be read in NUMSEC different times.

At this point, the basic data set has been entered into the program and precipitator performance will be projected based on this data. The last card in the data section must have a 99 in columns 1-2. This causes the program to terminate normally.

CONSTRUCTION OF SHORTENED DATA SETS

Once the basic data set is processed, then all the parameters which are needed by the program to calculate precipitator performance are stored in memory. By using values of NDATA equal to 2, 3, or 4, shortened data sets can be entered after the basic data set in order to analyze the effects of particle size distribution, specific collection area, and electrical conditions on precipitator performance. In the shortened data sets, the values of a small number of variables which are stored in memory are changed to new values in order to produce a new set of data.

In each shortened data set, the first two data groups and data cards which are read in are the same as those discussed for the basic data set. The value of NDATA on the first data card determines the variables in memory that will be changed. The effects of particle size distribution on precipitator performance can be analyzed by setting NDATA = 2. In this case, the third data group which is read in depends upon the value of NDIST which is stored in memory. If NDIST = 2, an inlet mass median diameter (D50) and geometric standard deviation (SIGMAP) must be read in

according to the same specifications discussed for the basic data set. If NDIST = 1, cumulative percents [PRCU(I)] corresponding to the particle sizes [ENDPT(I)] stored in memory must be read in according to the same specifications discussed for the basic data set. After the third data group is read in, the shortened data set is complete. By repeating this type of shortened data with different choices of D50 and SIGMAP or PRCU(I), the effects of particle size distribution can be analyzed with the use of only a few data cards.

The effects of specific collection area (SCA) on precipitator performance can be analyzed by setting NDATA = 3. In this case, the following is a sequential listing of the variables which are inputted in the third data group, along with the descriptions of the variables and the format specifications.

(1) VGS(I) is the total gas volume flow rate in a given electrical section and is in units of actual ft^3/min. The values of this variable are read in with an E11.4 format and must be right justified in columns 1-11, 23-33, and 45-55.

(2) VGASS(I) is the gas velocity in a given electrical section and is in units of ft/sec. The values of this variable are read in with an E11.4 format and must be right justified in columns 12-22, 34-44, and 56-66.

There must be a value of VGS(I) and VGASS(I) entered for each electrical section. The overall format for this data group is [3(2E11.4)] and the data group is contained on 4 or less cards depending on the value of NUMSEC which is stored in memory. For NUMSEC $\leq$ 3, 3<NUMSEC $\leq$ 6, 6<NUMSEC $\leq$ 9, and NUMSEC = 10, the number of data cards necessary are 1, 2, 3, and 4, respectively.

After this data group is read in, the shortened data set is complete. By repeating this type of shortened data set with different choices of VGS(I) and VGASS(I), the effects of specific collection area can be analyzed with the use of only a few data cards.

The effects of applied voltage and current on precipitator performance can be analyzed by setting NDATA = 4. In this case, the following is a sequential listing of the variables which are inputted in the third data group, along with the descriptions of the variables and the format specifications.

(1) VOS(I) is the applied voltage in a given electrical section and is in units of volts. If the value of NVI stored in memory is 1, the value of VOS(I)

corresponds to a measured or known value. If the value of NVI stored in memory is 2, VOS(I) corresponds to an applied voltage up to which a voltage-current curve will be calculated. Then, this applied voltage along with the corresponding current will be used in the calculation of precipitator performance. The values of this variable are read in with an E11.4 format and must be right justified in columns 1-11, 23-33, and 45-55.

(2) TCS(I) is the total current in a given electrical section and is in units of amperes. If the value of NVI stored in memory is 1, TCS(I) corresponds to a measured or known value. If the value of NVI stored in memory is 2, TCS(I) has no meaning in terms of input data since it will be calculated in the program. In this case, the appropriate columns on the data cards can be left blank or any arbitrary number can be enetered. The values of this variable are read in with an E11.4 format and must be right justified in columns 12-22, 34-44, and 56-66.

There must be a value of VOS(I) and TCS(I) entered for each electrical section. The overall format for this data group is [3(2E11.4)] and the data group is contained on 4 or less cards depending on the value of NUMSEC which is stored in memory. For NUMSEC $\leq$ 3, 3<NUMSEC $\leq$ 6, 6<NUMSEC $\leq$ 9, and NUMSEC = 10, the number of data cards necessary are 1, 2, 3, and 4, respectively.

After this data group is read in, the shortened data set is complete. By repeating this type of shortened data set with different choices of VOS(I) and TCS(I), the effects of voltage and current can be analyzed with the use of only a few data cards.

DYNAMIC RAPPING DATA SET

If NRAP $\neq$ 0 on the first data card, then additional data will need to be read into the program for the dynamic rapping process. This data, which is defined below, follows the basic data set. The maximum number of incremental lengths is limited to 45 when dynamic rapping is used.

(1) TIMRAP is the time at which a rap occurs. This variable is read in with an F10.5 format in columns 1-10. TIMRAP is specified in minutes.

(2) MAPRAP(I) is an indicator which specifies which increments of the precipitator are included in the rap. (These increments are the same calculation increments

defined by the variable LSECT in the basic data set.) Since the maximum number of increments is 45, MAPRAP is read in with a 45I1 format. If TIMRAP > 0 and MAPRAP(I) > 0, then the Ith increment of the precipitator is defined as having been rapped. The program sets the dust thickness on the collection plate at increment I equal to 0 and stores a portion of the collected dust for reintroduction into the gas flow at that point. If TIMRAP > 0 and MAPRAP(I) = 0, then the Ith increment was not rapped. If TIMRAP = 0 and MAPRAP(1) ≠ 0, the program will treat the next card as the beginning of an all new rapping scheme. In this case, the next card read in will be the first TIMRAP card of the new scheme. If TIMRAP = 0 and MAPRAP(1) = 0, the rapping calculation is terminated and the program resumes normal operation. The next card that will be read in this case is card 1 of the basic data set. MAPRAP is located in columns 11-55.

(3) REPCT — is the fraction of the dust collected in one electrical section that is reentrained during the time required for the gas to flow past one computational length increment, LINCS. This is defined by

$$\text{REPCT} = \frac{F}{\text{NLANES}} * \frac{\text{Duration of gas flow past one increment}}{\text{Total duration of each rapping puff}},$$

where F is the total fraction of the collected dust that will be reentrained during a rap and NLANES is the number of parallel lanes in the section which are rapped at different times.

(4) NUMBOL — is the number of data points in the reentrainment profile. NUMBOL is read in with an I2 format and must be right justified in columns 61-65.

(5) NDAT — is an indicator which can assume the values of 0 or 1. If NDAT = 1, the subsequent cards will define the rapping profile. If NDAT = 0, the existing rapping profile will be used in this rap. NDAT is read in with an I5 format and must be right justified in columns 66-70.

The overall format for this card is (F10.5, 45I1, F5.3, 2I5). This card is used to define each rap of the precipitator. If two or more sections of the precipitator are rapped at the same time, a single card can contain all of the necessary information. However, any rap which occurs at a different time will require another TIMRAP card.

If NDAT = 1 on the TIMRAP card, the following cards must be inserted following that card to define the rapping profile:

(1) BOLFRC(I,J) are the data points used to construct the normalized histogram of fractions of dust reentrained in a given time interval. There must be NUMBOL values of BOLFRC on the card. BOLFRC is read into the program with an F6.3 format.

The overal format of this card is (13F6.3). The program expects the number of BOLFRC cards to equal the number of precipitator sections (NUMSEC) so that a different reentrainment histogram may be read in for each section. After NUMSEC cards are read, the following data is expected:

(1) REMMD(I,J) are the mass median diameters for a log-normal size distribution associated with each step of the histrogram defined by BOLFRC(I,J). There must be NUMBOL values of REMMD on the card. REMMD is read with an F6.3 format and must be in units of μm.

(2) RESIG(J) is the geometric standard deviation of the log-normal size distributions defined by REMMD. The value of RESIG must be equal to or greater than 1. RESIG is read in an F6.3 format immediately following the last value of REMMD(I,J).

The overall format of this card is (13F6.3). The program expects to read NUMSEC REMMD cards to match the NUMSEC BOLFRC cards. After these cards are used, the following card is read in:

(1) BOLTIM(I) are the durations in seconds of each of the steps of the rapping histogram. The sum of the values of BOLTIM(I) is the total duration of the rapping emissions and must obey the following relation:

$$\Sigma \text{ Boltim(I)} = \text{NLANES} * \text{Total duration of each rapping puff}$$

The total duration of the rapping emissions must not exceed the time between raps as the model cannot correct for overlapping rapping puffs. There must be NUMBOL values of BOLTIM on the card in an F6.3 format.

(2) DDRAP — is the particle density of the reentrained dust. DD rap is in units of kg/m^3 and is read in with an F6.3 format.

The overall format of this card is (13F6.3). Only 1 BOLTIM card will be read in as the durations of the steps in the histogram are assumed to be the same for all sections of the precipitator. The rapping profile must be read in after the first TIMRAP card. Thereafter, it may be read in if it is changed. After the BOLTIM card is read in, the next card expected by the program is a new TIMRAP card.

OPACITY DATA SET

In the calculation of precipitator outlet opacity, additional data is required if NCOMPS is greater than 0. If NCOMPS > 0 and NLAMDA = 0, user supplied values of the read and imaginary parts of the index of refraction must be read into the program:

(1) CMR(I) — is the real part of the user supplied index of refraction. This quantity is read in with an F5.3 format.

(2) CMI(I) — is the imaginery part of the user supplied index of refraction. CMI(I) is read with an F5.3 format.

The NCOMPS values of CMR(I) and CMI(I) are read in as data pairs with an overall format of [6(2F5.3)].

If NCOMPS > 0 and NLAMDA > 0, then the index of refraction changes with wavelength. In this case the following data are read in:

(1) CMR(J) — is the real part of the user supplied index of refraction for wavelengths ranging from the value of UPTOLM(J-1) (assumed to be 0.43 μm if J = 1) to the value of UPTOLM(J). CMR is read in with an F5.3 format.

(2) CMI(J) — is the imaginary part of the user supplied index of refraction for wavelengths ranging from the value of UPTOLM(J-1) to the value of UPTOLM(J). CMI is read in with an F5.3 format.

(3) UPTOLM(J) — is the upper limit of the wavelength band for which CMR(J) and CMI(J) are the correct indices of refraction. UPTOLM is in units of μm and is read in with an F5.3 format. The final value of UPTOLM(J) must be equal to or greater than 0.70.

The NLAMDA values of CMR(J), CMI(J), and UPTOLM(J) are read in the form of data groups, each complete for a given value of J. The overall format for this data is [4(3F5.2)].

UNKNOWN OPERATING CONDITIONS

The model may be used to calculate voltage-current curves and collection efficiencies for precipitators with unknown operating voltages and currents. Table A-4 summaries the options available to the user and makes recommendations on the applicability of each. If collection efficiency data for a utility fly ash precipitator is desired, the following data set should be used.

The first data card has the same format as the first card in the basic data set. MODL must be set to 2 in column 8. Since the remainder of the data in this data group is redefined in subroutine INTERN, the rest of the card may be left blank if desired.

Data group 2 contains the following 2 data.

(1) RHO — is the resistivity of the collected particulate layer expressed in ohm-cm. RHO is entered with an E8.2 format and must be right justified in columns 1-8.

(2) HDUCT — is the wire-to-plate spacing in units of inches. HDUCT is read with an F5.2 format in columns 11-15.

If the ESP being studied is similar to a utility fly ash precipitator, the above procedure may be used. However, if the ESP is much different from a utility fly ash precipitator, a different procedure should be used. This procedure is enabled when NVI is set to 2 in data group 3. The description of the data required for this case is contained in the construction of the basic data set section of this Appendix (p. A-1).

If only voltage-current curves are desired, the required data set again depends on whether the ESP is similar to a utility fly ash precipitator. If the ESP is similar, then the first 3 data groups are the same as for the basic data set described earlier in this Appendix. To get the voltage-current calculation, the following values must appear:

(1) Card 1: MODL = 3 in column 8 (the rest of the card may be blank), and

(2) Card 3: NVI = 1 in column 6 (the rest of the card may be blank).

TABLE A-4. USER OPTIONS WHEN THE OPERATING VOLTAGE AND CURRENT ARE NOT KNOWN

Desired Calculation	Variables MODL	NVI	VISKIP	VISAME	Procedure Recommended	Comments
Collection efficiency of a utility fly ash precipitator.	2	1	n/a	n/a	Yes	Uses internal data set based on 17 field tests of cold-side utility fly ash precipitators to generate efficiencies for a range of SCA values. Fast.
	0 or 1	2	1	1 or 2	No	Calculates approximate V-I curves; then calculates efficiency for a derived operating point. Slow. VISAME=2 (different voltages in each section) is slower than VISAME=1 (same voltage).
Collection efficiency for an ESP that is much different from a utility fly ash ESP.	2	1	n/a	n/a	No	Precipitator test data used in internal data set are not similar to this application. Accuracy may be low. Fast.
	0 or 1	2	1	1	Yes	Calculates approximate voltage-current curves; then calculates efficiency for a derived operating point. Uses the same operating point in each ESP section. Slow.
	0 or 1	2	1	2	No	Same as above except calculates a new operating point for each ESP section. Slower.
	0 or 1	2	0	2	No	Same as above except calculates electric fields and potentials in each ESP length increment. Very slow.

(continued)

TABLE A-4. (CONTINUED)

Desired Calculation	Variables MODL	NVI	VISKIP	VISAME	Procedure Recommended	Comments
Voltage-current curves only for a utility fly ash precipitator.	3	1	n/a	n/a	Yes	Uses internal data set to generate voltage-current curves. No efficiency calculated. Fast.
	3	2	1	1 or 2	No	Calculates voltage-current curve for first section only using approximate procedures. No efficiency calculated. Slow.
Voltage-current curves only for an ESP that is much different from a utility fly ash ESP.	3	1	n/a	n/a	No	Uses internal data set to generate voltage-current curves. Precipitator test data used in internal data set are not similar to this application. Accuracy may be low. Fast.
	3	2	1	1 or 2	Yes	Calculates voltage-current curve for first section only using approximate procedures. No efficiency calculated. Slower.

Card 4 will contain the following data:

(1) RHO — is the resistivity of the collected particulate layer expressed in ohm-cm. RHO is entered with an E8.2 format and must be right justified in columns 1-8.

(2) HDUCT — is the wire-to-plate spacing in units of inches. HDUCT is read with an F5.2 format in columns 11-15.

Voltage-current curves and operating points for a six section ESP will be printed. If the ESP is not similar to a utility fly ash precipitator, a complete data set appropriate for an efficiency calculation with NVI set to 2 is required. If MODL = 3 on card 1, the calculation will terminate after the calculation and printing of the voltage-current curve data for the first electrical section.

REFERENCE

1. Faulkner, M. G., and DuBard, J. L. A Mathematical Model of Electrostatic Precipitation (Revision 3). EPA-600/7-84-069a,b,c. (Volume I, Modeling and Programming: NTIS PB84-212-679; Volume II, User's Manual: NTIS PB84-212-687; FORTRAN Source Code Tape: NTIS PB84-232-990). U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. 1984.

Appendix B

DATA FORMS

Data For:

Get Data From:

Store Data In:

CALCULATION PARAMETERS

****

Title:

Amount of printing [-1 most, 0 standard, 1 less, 2 least] _____
Estimations (fast) or Rigorous calculations (slow) [E or R] _____
Cold side or Hot side [C or H] _____

Estimated efficiency _____ %

PHYSICAL DATA

****

Inlet mass loading	DL	_____	gr/acf
Particle density	DD	_____	kg/m3
Ash resistivity	RHO	_____	ohm-cm
Percent water	PCH2O	_____	%
Percent oxygen	PCO2	_____	%
Ion mobility (typically .00027)	US	_____	m2/V/s
Dielectric ratio (typically 100)	EPS	_____	
Peak-to-average voltage ratio (typically 1.2)	VRATIO	_____	

PARTICLE SIZE DATA

****

Number of size band end points — NENDPT _____

Type of size data — NDIST _____
1 = cumulative percent mass
2 = mmd and sigma

mmd _____
sigma _____

endpoints
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____
21. _____

cumulative %
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____
21. _____

SECTIONAL DATA

****

Number of fields in gas flow direction NUMSEC _____

No. length increments per field (Total cannot exceed 99) LSECT _____ length of field _____ ft

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

****

FIELD NO.		_____	_____	_____	
Voltage	VOS	_____	_____	_____	V
Current	TCS	_____	_____	_____	A
Plate area	AS	_____	_____	_____	ft2
Total wire length	WLS	_____	_____	_____	ft
Corona wire radius	ACS	_____	_____	_____	in.
Number of wires per lane	NWS	_____	_____	_____	
Wire-to-plate spacing	BS	_____	_____	_____	in.
Wire-to-wire spacing	SYS*2	_____	_____	_____	in.
Gas volume flow rate	VGS	_____	_____	_____	acfm
Gas velocity	VGASS	_____	_____	_____	ft/s
Gas temperature	TEMPS	_____	_____	_____	deg F
Gas pressure	PS	_____	_____	_____	atm

FIELD NO.		_____	_____	_____	
Voltage	VOS	_____	_____	_____	V
Current	TCS	_____	_____	_____	A
Plate area	AS	_____	_____	_____	ft2
Total wire length	WLS	_____	_____	_____	ft
Corona wire radius	ACS	_____	_____	_____	in.
Number of wires per lane	NWS	_____	_____	_____	
Wire-to-plate spacing	BS	_____	_____	_____	in.
Wire-to-wire spacing	SYS*2	_____	_____	_____	in.
Gas volume flow rate	VGS	_____	_____	_____	acfm
Gas velocity	VGASS	_____	_____	_____	ft/s
Gas temperature	TEMPS	_____	_____	_____	deg F
Gas pressure	PS	_____	_____	_____	atm

SNEAKAGE AND SIGMA G

****

Number of sneakage / sigma g data sets NONID _____

Sneakage fraction	Gas vel. sigma	No. baffles
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

OPACITY

****

Opacity calculation desired (Y = yes, N = no) _____

Opacity path length PATHL _____ ft

RAPPING SIZE DISTRIBUTION DATA

****

First rapping puff size distribution (mmd = 6.0 um, sigma = 2.5) is built in

Number of rapping size distributions NRAPD _____
(= 1 + number of additional distribution)

Additional rapping mmd	Additional sigma
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____